U.S. Army Research Institute
for the Behavioral and Social Sciences

Research Report 1916

Asymmetric Attention: Visualizing the Uncertain Threat

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U. S. Army Research Institute

March 2010

U.S. Army Research Institute
for the Behavioral and Social Sciences

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REPORT DOCUMENTATION PAGE

1. REPORT DATE (dd-mm-yy) March 2010	2. REPORT TYPE Final	3. DATES COVERED (from. . . to) September 2008 – September 2009
4. TITLE AND SUBTITLE Asymmetric Attention: Visualizing the Uncertain Threat		5a. CONTRACT OR GRANT NUMBER 5b. PROGRAM ELEMENT NUMBER 622785
6. AUTHOR(S) Christopher L. Vowels (U.S. Army Research Institute)		5c. PROJECT NUMBER A790 5d. TASK NUMBER 331 5e. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences ATTN: DAPE-ARI-IK 761st Tank Battalion Avenue, Bldg. 33009 Ft. Hood, TX 76544		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences ATTN: DAPE-ARI-IK 2511 Jefferson Davis Highway Arlington, VA 22202-3926		10. MONITOR ACRONYM ARI 11. MONITOR REPORT NUMBER Research Report 1916

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

Subject Matter POC: Christopher L. Vowels

14. ABSTRACT *(Maximum 200 words)*:

This report attempts to fuse Army needs, specific to threat detection, with available evidence from academia and military sources. The report provides viable routes for short-term enhancement of threat detection training and long-term goals of a research program dedicated to improving the Army's understanding of threat detection. This review found two major avenues of research, visual attention and visual memory that would benefit research and understanding of attention and threat detection for current and future operational environments. Based on the review, at least three sequential skills are discussed as necessary for understanding and improving threat detection: attentiveness, recognition, and action. These skills orient and guide the Soldier in operational settings from the basic perceptual process at the attentiveness stage up through higher-order reasoning at the action stage. Training formats are explored including still images and high-fidelity simulations, all of which could be scaffolded upon a deliberate practice framework.

15. SUBJECT TERMS

Attention, infantry, threat, threat detection, IED, sniper, patrol, convoy, reconnaissance, irregular warfare, asymmetric warfare

SECURITY CLASSIFICATION OF			19. LIMITATION OF ABSTRACT	20. NUMBER OF PAGES	21. RESPONSIBLE PERSON
16. REPORT	17. ABSTRACT	18. THIS PAGE			
Unclassified	Unclassified	Unclassified	Unlimited	56	Ellen Kinzer Technical Publications Specialist 703-602-8049

Standard Form 298

Research Report 1916

Asymmetric Attention: Visualizing the Uncertain Threat

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March2010

Army Project Number	**Personnel, Performance**
622785A790	**and Training Technology**

ACKNOWLEDGEMENTS

I offer my sincere thanks to the Soldiers who have provided insights on the present topic and continue to assist in the author's understanding of contemporary operations. I would also like to thank Barbara Black, Jeffrey Fite, Carl Lickteig, Jim Lussier, William Sanders, Michelle Sams, and Scott Shadrick, for making key comments and providing accurately, critical suggestions, all of which improved the quality of the document.

ASYMMETRIC ATTENTION: VISUALIZING THE UNCERTAIN THREAT

EXECUTIVE SUMMARY

Research Requirement:

Given the U.S. Army's continued emphasis on both combative and non-combative operations, the ability of threat detection was explored to create a foundation of understanding for future research and training development. The Army continues to conduct both mounted and dismounted reconnaissance and patrols as part of its regular operations. A fundamental aspect of those operations is the ability to detect and defeat a variety of threats within an irregular warfare environment. In order to address current understanding of threat through academic and military lenses, and to provide potential means for researching and improving upon current training, a literature search of academic and military sources was conducted.

Procedure:

Many sources relevant for threat detection, especially visual attention and visual memory were reviewed. Military doctrine, such as FM 3-24, *Counterinsurgency*, and *Irregular Warfare Joint Operating Concept*, and websites dedicated to providing recent understanding of the operational environment (i.e., Center for Army Lessons Learned) were reviewed for contemporary views and understanding of threat detection. In addition to the literature review, Soldiers with recent deployment experience were interviewed to gather their experiences involving threat detection in current operational environments.

Findings:

This review established two major avenues of research, visual attention and visual memory, that would benefit research and understanding of threat detection (TD) for current and future operational environments. Based on the review, at least three sequential skills were found to be relevant for understanding and improving TD: attentiveness, recognition, and action. These skills orient and guide the Soldier in operational settings from the basic perceptual process at the attentiveness stage up through higher-order reasoning at the action stage. Research and training programs should also consider three core contexts of interaction, including human: human interactions (such as monitoring verbal and non-verbal behavior), human: terrain interactions (such as scanning the terrain for emplaced threats), and human: computer interactions (such as monitoring computer displays for threat cues).

Utilization and Dissemination of Findings:

The findings in this report serve as a foundation for establishing a research program and a source for potential training applications on TD by providing an emphasis on the key variables illustrated from academia and current military doctrine and first-hand knowledge and experience of recently deployed Soldiers. The present review serves as an initial effort to accomplish the endstate, which is to establish a long-term research program to improve the Army's

understanding of TD and provide the Army with continual research and training applications directly resulting from the effort. At the individual level, the endstate is to provide Soldiers with a skill set that allows them to better detect, evaluate, and defeat a variety of threats in the operational environment.

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"The need to keep my men alive makes everything else negotiable,
and everyone and everything a potential threat."

SSG Bellavia
House to House

"The number one issue currently facing Soldiers is threat identification."

LTC Bagwell

Introduction

Soldiers in today's Operational Environment (OE) must excel in their cognitive and perceptual skills, particularly visual attentiveness, for successful threat detection (TD) and response. Specific skills such as attention to detail, detection and recognition of lethal and non-lethal threat cues, and deterring and countering threats are requisite for units performing dismounted and mounted operations (Center for Army Lessons Learned, 2008). Training and planning guidance for deployment stresses that these skills are necessary in theatre (Department of Army [DA], 2006). Further, the challenge of full spectrum readiness requires that Soldiers acquire and maintain the TD skills in multiple and varied conflicts in the context of rapid deployment/redeployment cycles and a mounting task load. Cognitive and perceptual skills are always necessary for maintaining the operational advantage, but they are particularly difficult to train and maintain for asymmetric environments due to high uncertainty and unpredictability embedded in those environments (X-File 3-35.3x, *Combat Hunter: Observe, Move and Act Tactics, Techniques and Procedures (TTPs*). As the Army has entered the era of "persistent conflict" it has to deal with and accurately assess hybrid threats which compound the difficulty of threat detection (Department of Army, [DA], 2009).

Detecting and evaluating threats in an asymmetric environment is never easy. As Field Manual (FM) 3-24, *Counterinsurgency*, emphasizes, insurgents look the same as the general population and deliberately blend with the local culture. Fortunately, threat detection benefits from understanding insurgent's level of coordination, what they hope to accomplish, and what opportunities insurgents might use to their advantage. Ideally, Soldiers performing TD are guided by a focused analytical skill and prior work to determine the validity and relative importance of threats and expected effects of engaging various threats. Detection is also aided by knowing the relationships between insurgents and their role in the local community, the Soldiers' Area of Operations (AO). Likewise, tracking non-insurgent threats such as criminal gang activity is requisite for TD due to their potential to become powerful elements that can be exploited by an insurgency. TD is further complicated for Soldiers in the OE by the wide range of insurgent activities including infiltration and subversion, denial and deception, and insurgent's use of a variety of weapons (FM 3-24).

The daunting task of detecting insurgent and non-insurgent threats underscores the need to develop training to improve TD in the OE. The Marine's Combat Hunter Course, for instance, fosters a mindset that encourages more accurate identification of enemy forces, lessens the risk to non-combatants, and increases survivability (Piper, 2008). The course teaches participants to

detect cues that indicate something is out of place such as the way persons are walking or acting; it underscores the need for Army training to improve Soldiers' TD skills.

Given the challenging nature of TD, this report proposes two complementary research programs to assist the Army's Soldiers' necessity to acquire and maintain TD skills. First, experimental issues and approaches relevant to TD are reviewed to provide the basis for developing a long-term research program to improve the Army's understanding of TD. Second, issues concerning the training of TD, including training methods and delivery methods suitable for institutional and unit training, are examined to guide research on training development and revision to improve Soldiers' TD performance.

Literature Background

This section identifies and reviews research issues in TD to guide future ARI research in TD training. The main TD research issues introduced here, and explored more in the Research Topics and Frameworks section, include: the irregular warfare environment, natural processing biases and goals, three interactive contexts, TD skills, and research frameworks. A review of the academic literature revealed several major factors involving attention and TD that are worthy of continued investigation and can aid in improving TD training and performance.

Dukewich and Klein (2009) explored which of three visual search processes (detection, localization, or identification) are most indicative of visual search performance either in the presence or absence of a target. They noted these processes are important for distinguishing between inferred search rate and actual search, which determines the amount of time it takes to acquire a target. Examining these processes is relevant for TD, because they are indicators of the amount of effort involved in searching for a target. They likewise serve as processes that can undergo further experimental investigation which may lead to enhanced TD training and performance.

A means for assessing detection of targets is through the study of focused attention. A common dichotomy for examining detection of change or the acquisition of static patterns is intentional versus incidental detection. The intentional condition is characterized by forewarning participants that they are looking for a cue versus the incidental condition which involves no forewarning, but still requires cue detection. Although, alerting participants potentially biases the results in the intentional condition due to forewarning, both conditions inform change detection research (Rensink, 2000). The intentional condition is often used to investigate perceptual capacities whereas the incidental condition is a good method for assessing the ability to process unexpected change (Rensink, 2000). Maintaining an appropriate level of realism versus examining natural processes in a controlled setting are both conditions that can aid TD research and training development by providing different insights into TD.

Likewise, the influence of memory on search and detection processes is another important consideration for understanding Soldiers' TD performance. The ability of Soldiers to intuitively react to threat situations can be aided by retrieving similar instances from memory (Klein, 2003) or from being aware that something is out of place in the area they have patrolled before. In a proposed theory linking attention and memory, Smith and Ratcliff (2009) describe a

model demonstrating that attention's role in processing information is to enhance formation of traces in visual short-term memory. This is supportive of earlier research by Engle (2002) suggesting that executive attention and working memory capacity are actually the same ability. Improving visual search performance of Soldiers, specifically for TD, requires an understanding of whether or not Soldiers must simply react to stimuli or whether they must rely mainly on memory (Dyer & Salter, 2001). In sum, research on TD should consider the processes specific to attention as well as the influence of memory on visual search.

The TD research has a strong foundation in more diverse research programs on attention and cue detection. For instance, related academic research on attention and cue detection includes the role of uncertainty in information available and how persons attempt to resolve complex visual problems and forecast future situations (Schunn, Saner, Kirschenbaum, Trafton, & Littleton, 2007; Trickett, Trafton, Saner, & Schunn, 2007). It also includes empirical research on the two critical pathways for abilities such as cue detection, specifically visual attention and visual memory (Hollingworth & Luck, 2009; Hollingworth, 2009). Another particularly notable program of research has examined the influence of an observer's expectations on visual search and attention (Dark, Vochatzer, & VanVoorhis, 1996). Likewise, recent work has illustrated that fear-invoking stimuli can affect general visual search proficiency (Becker, 2009; Becker & Detweiler-Bedell, 2009). All of the above findings reveal important considerations for examining TD, since the characteristics noted directly affect attention and the ability to detect cues.

Soldiers need to be aware of the changes in their environment and how their presence directly impacts the environments in which they operate. For dismounted Soldiers, the environment they operate in is potentially unforgiving and dynamic. As a Soldier acts or does not, the environment shifts (or may appear not to) in direct response to the Soldier's behavior. An example of such research for vision and perception is that of J.J. Gibson (1986), who emphasized the importance of not just what the observer brings to perception or what information is available in the environment, but the continual observer-environment interaction. Understanding that the environment is full of information flowing to and from each Soldier may be a difficult perspective for Soldiers to grasp and maintain. However, a guerilla warfare environment is full of uncertainty, taking two forms: noise and information. Being fully aware of a situation in order to make accurate decisions is critical in many contexts (Endsley, 2003) as is being able to make rapid decisions under stressful (Gladwell, 2005). Although we have innate mechanisms for dealing with uncertainty, those mechanisms can often lead to less than optimal outcomes (Tversky & Kahneman, 1974; Tversky, 2004). This concept is a potentially vital perspective to instill in Soldiers, because the presence and activity of Soldiers significantly impacts their OEs. Correctly managing change, particularly the changes a Soldier induces, is an essential skill for an adaptive Soldier in an irregular environment. Soldiers with recent deployment experience have noted that dealing with the enormous amount of information is a difficult task to train for, but becomes more manageable with experience.

In dynamic environments such as military and sport domains, attention is regarded as "the most proximal predictor of quality performance" (Janelle & Hatfield, 2008, p. S41). In such domains, the most important factor for high-level performance is attention to the right things at the right time. In Janelle and Hatfield's conceptual framework of sport expertise, virtually all

psychological factors involved in performance underlie the ability to attend appropriately. Military and sport environments are characterized by a high degree of uncertainty and potential threat. When facing uncertainty, a dominant human reaction is often concern and preoccupation with the unknown that causes shifts in attention to external and internal cues as well as performance capabilities. To understand and counter inappropriate shifts, researchers like Janelle and Hatfield (2008) have focused on understanding those factors that influence, either positively or negatively, the ability to attend appropriately in dynamic domains and dynamic emotional states, such as anxiety.

Multiple skills are required to complete the perception-action cycle from TD to response, including: attentiveness, recognition, and action. Attentiveness entails the mental, emotional, and physical process that triggers the detection of threat cues. Recognition is determining if detected cues indicate threat and need further processing. Action is the behavioral response(s) to the threat including overt acts and covert mental processes, such as searching memory and updating one's mental model. Visual attentiveness requires a preparedness to process important cues in the environment with reliance on visual memory, though a potentially unconscious process (Finkbeiner & Palermo, 2009). Conversely, the avoidance of inattention requires an awareness of when attentional resources fall below an operational threshold. A good example of the perception-action cycle in detection is provided by Kowalski-Trakofler and Barrett (2003) in their research on degraded image training for coal mine workers using a sequential process model involving the skills of TD. They found that using degraded images in training improved hazard detection performance whereas using regular images did not. A major factor that makes any battlefield dangerous is not knowing there is a problem until it is too late. This is certainly true for irregular environments.

Training on attention and attentional control has been supported by various research efforts. Brickner and Gopher (1981) found that participants taught to focus on certain aspects of task performance improved with practice. Further, performance may be aided by utilizing certain attentional strategies which have been shown to impact long-range performance. For example, when training involved assigning varying degrees of attention to parts of a task, the trained persons often outperformed persons who received more practice on the criterion task (Gopher, 1993). Trained persons also exhibited better transfer performance on similar, but novel tasks (Kramer, Larish, & Strayer, 1995).

Related research by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) on attention and TD includes research on improvised explosive device (IED) detection (Leipold, 2009) and research on change detection and change blindness (Durlach, Kring, & Bowens, 2008). As cited by Leipold, Murphy's research examined what inherent elements a person needs to qualify as an expert at detecting IEDs (Murphy, 2009). Durlach's research program has examined what factors, such as type of visual distractors, influence change detection in visual displays. Establishing an expert model of TD is key to utilizing behavior as a means for selecting individuals inherently good at certain duties, such as IED detection and for better understanding natural or trained behaviors experts rely on for specific duties such as mine detection (Stazweski, 1999). Other ARI research has focused on stressors such as fatigue and its effect on attention and vigilance, which are important factors to consider for TD research and training (Fuller, 1983). ARI has also focused on necessary TD skills such as tracking and

engaging moving targets under various conditions (Schendel & Johnston, 1982). Further, understanding how and why TD experts perform the way they do can serve the function of enhancing training aimed at establishing expert performance. However, whether such skills are consistently trainable across Soldiers up to an expert level and applicable for animate TD (i.e., human interaction) and inanimate TD (i.e., IEDs) remains to be determined.

Military Background

Threat detection in today's OE is fundamentally a human performance challenge. In response to that challenge, the Army has equipped Soldiers with many advanced detection technologies. However, Soldiers may not utilize these resources for various reasons (Cohen, April 2009), including: no immediate or direct benefit for the Soldier using it, the technologies do not flex with the Soldiers' needs, nor help Soldiers communicate what events have taken place. Likewise, Soldiers can become dependent on such equipment and complacent due to their reliance on them. Unfortunately, technologies fail. If a technology fails, is simply not available, or when Soldiers have not been properly trained on the equipment, Soldiers must still execute their missions in a concerted effort; they must rely on their perceptual and cognitive skills. Even at the most basic skill level, all of the battle drills for instance, involve responding to threat by relying, not on technology, but by using inherent abilities and trained skills (STP-21-1-SMCT, Dec 2007). Understanding the human dimension, especially in terms of cognition, vigilance, and attentiveness is a current and future focus for the Army (Steinburg & Kornguth, 2009).

Asymmetric wars are local. Soldiers cannot forget the lessons of past operations in guerilla or asymmetric environments, such as understanding the local community dynamics (Nagl, 2002). McMaster (2009) warns that being remiss about the cultural, political, geographical, and economic environments have hampered current operations in Iraq and Afghanistan just as being ignorant of such characteristics led to a failed strategy in Vietnam. Nagl (2009) advises that the wars we are in are far from over and that the focus should be on developing an Army that can adjust to contemporary warfare environments. Nevertheless, there is a need to develop Soldiers who can meld experiences from past operations with needs of current and future warfare, including understanding the local populace.

As the Army continues to face irregular warfare environments, it has shifted from mainly conducting conventional warfare to also conducting operations other than war, such as governance legitimacy (Fite, Breidert, & Shadrick, 2009). Soldiers must now attain and maintain a diverse set of skills required to perform basic operations such as guarding a check point to forming relationships with local citizens and officials, all of which involve some level of TD. These tasks must be accomplished by adaptive Soldiers relying on their trained abilities to execute diverse and even unanticipated missions. For instance, route clearance depends not only on the TD technology available to Soldiers, but primarily Soldiers' ability to visually detect potential threats, especially when dismounted (Center for Army Lessons Learned, 2008). A primary task of every Soldier in the OE is to manage information, especially detection of threats. However, understanding how to separate relevant information from irrelevant and detecting and managing pertinent cues requires training and expertise (Janelle & Hatfield, 2008).

Scales (2009) recounts Clausewitz's thoughts on information gathering, such that Soldiers must carry with them the ability to intuitively process their environment to make quick and unaided responses, particularly concerning the intentions of others in their environment. A Soldier's capacity for understanding the enemy is not shaped only by the military's organizational culture, but is influenced by a more pronounced 'psycho-cultural' perspective. Due to our 'sheltered' and western societal background, our citizens' understanding and ability to engage in adaptive awareness of other cultures is limited. Scales notes, "Culture awareness and the ability to build ties of trust will offer protection to our troops more effectively than body armor" (pg. S27). Thus, today's Soldiers have to be "highly trained and agile responders" considering the amount and complexity of information that they are being asked to handle (Steinburg & Kornguth, 2009). Soldiers are impeded by a psycho-cultural perspective, require an understanding of past lessons, and have an obligation to execute a variety of missions in the OE, whether the technological support or time to train is available or not.

A leading tenet of current doctrine is that Soldiers must evaluate the threat which includes knowing the enemy's capacity to emplace threats in the OE as well as understanding the enemy's susceptibility to coalition actions (e.g., FM 3-24). Likewise, effective TD is knowing what targets to engage and to comprehensively understand the effects of attempting to exploit those targets, whether successful or not. For higher-level planning and analysis, the performance and assessment of operations must encompass not just immediate battlespace effects, but also potential second- and third-order effects on the cultural and geo-political structure of the local and regional environments (FM 3-06, *Urban Operations*). Likewise, Soldiers on the ground must have the means to execute TD and the means to assimilate and transfer information up the chain of command for further analysis. This continuity of information exchange allows commanders at various levels of command to maintain their situational awareness (TRADOC Pamphlet 525-3-2, *Tactical Maneuver*). Skills such as attentiveness and its maintenance for the Soldier need training emphasis, especially when those skills are required in high-stress environments (multiple information sources, limited time to execute, asymmetric). Attentional skills are also necessary when the threat environment appears low-stress; a seemingly docile environment can placate even the attentive Soldier.

A major challenge in training TD, and many other skills, is time available to train. A potential means for overcoming the lack of time to develop, deliver, and assess training is to integrate training on TD into extant training and operational exercises. The perceptual and cognitive skills at the foundation of training on TD can be integrated into a variety of mission preparation and rehearsal exercises ranging from non-verbal interpersonal communication to convoy operations. Viewing TD skills as integral to Soldier performance may be the most efficient and effective means of delivering TD training without adding a large time commitment to already overburdened units. Training TD should accomplish five objectives: reduce errors, increase performance speed, increase flexibility of the desired skills, increase the robustness of the desired skills, and increase skill retention (see Taatgen, Huss, Dickison, & Anderson, 2008 for a review of skill acquisition models). Those TD objectives, discussed more thoroughly in the Training Issues and Approaches section, can be achieved and the Army better prepared by selecting the best training methods applicable to the broadest training audience. An integrated, multi-method approach from the school house to unit-focused training is likely to yield the most effective results.

Whenever possible, the training should closely resemble the real environments Soldiers are operating in. Training environments must provide depth and deliberate practice across different skills, such that the obtained skills improve Soldiers' ability to react and adapt to any given environment, rapidly and effectively. For instance, recent interviews with Soldiers serving as the Opposing Force (OPFOR) at the Joint Readiness Training Center (JRTC) illustrated that information must be assessed and integrated quickly, in order to maximize time available to complete mission objectives (Dyer, Centric, & Wampler, 2007). Since JRTC provides a close approximation to actual operations in theatre, the training experience at JRTC, and other operational exercises, provide valuable training opportunities. However, not all skills are trained in operational settings due largely to lack of personnel and time constraints. Thus, synthetic learning environments, such as simulations or online interactive programs, can serve as the conduit to achieve any further training, regardless of unit location.

Synthetic training experiences, which often supplement traditional school-house learning, can take various forms such as online multimedia and interactive programs, including films that are carefully designed to match contemporary learning principles (Hill, et al., 2008). At least, synthetic experiences provide a less costly, yet effective, modality teaching complex skills, including interpersonal communication between persons of same and different cultural backgrounds (Zbylut et al., 2007). Likewise, training involving synthetic environments has shown skill improvement in adaptive thinking (Shadrick, Crabb, Lussier, & Burke, 2007) and responding to crises (Shadrick, Schaefer, & Beaubien, 2007; Schaefer, Shadrick, Beaubien, & Crabb, 2008). When overlaid with proper training techniques and objectives, increasingly powerful synthetic training experiences may provide an effective learning experience (FM 7-0). For instance, *Virtual Battlespace 2* (*VBS2*), a three-dimensional interactive simulation system, provides a variety of realistic settings and perspectives likely to be encountered in the OE, suitable for training TD.

If time is available to train and training formats have been chosen, determining the appropriate level to train to before deployment becomes an important research and training issue. What level to train to requires a look at the continuum of performance, novice through expert. One of the most important distinguishing factors between novices and experts is the kind of information used, not necessarily just the amount of it (Shanteau, 1992a). Experts are also able to quickly see the big picture and find solutions rather focus on only pieces of a problem Shanteau, 1992b). The high level of knowledge and ability is also usually bound within a specific domain (Shanteau, 1987; see also Werner & Thies, 2000). These characteristics hold true in constrained environments, such as those involving time pressure (Stokes, Kemper, & Kite, 1997). Thus, experience can lead to the acquisition of the ability to distinguish relevant information from irrelevant and, likewise, what to do with either form when necessary (See Klein, 1997). The ability to manage and react appropriately to information on the battlefield distinguishes the experts from the novices. However, to acquire TD expertise Soldiers may require a complementary mix of training and experience. Coupling a multi-method training approach with units who understand and promote learning on the battlefield creates an expert force that can execute TD in a variety of environments (Dubik, 2009).

Understanding how performance is measured is a key factor not only in studying military behavior, but especially for training and assessing expert behavior. Drawing upon evidence from

sport psychology, Williams, Ericsson, Ward, and Eccles (2008) review a framework for effectively capturing expert behavior regardless of field of study. Adaptability of a unit to a battlefield determines its success, but being able to assess this performance is the means to develop training for future units and to develop doctrine that tracks with recent lessons learned (Dubik, 2009).

Ensuring that training allows Soldiers to reach their needed level of performance is paramount for military operations. While initial training receives a great deal of attention, maintenance and retention of necessary skills may receive less, especially during times of war and rapid re-deployment cycles. As noted in the ARI Special Report 39 (Wisher, Sabol, & Ellis, 1999), skills of different types (i.e., continuous vs. discrete procedural skills) may decay at different rates. Thus, initial training needs to vary in form and substance by skill type and re-training may be required at different points of time in the future. Cognitive and perceptual skills, specifically visual attentiveness, can be tested and re-trained frequently with relatively minimal time and cost to better prevent skill decay. By combining TD training and assessment with extant training, time and money may be saved and training objectives more sufficiently and effectively met. The next section examines some of the TD topics and frameworks that should be addressed to guide the development of research and training methodologies and tools to improve Soldiers' TD performance.

Research Topics and Frameworks

The research program proposed in this report would address research and training topics by examining visual attention and visual memory both as separate and combined processes that aid in TD training and in the development of models of expert threat detection ability. Projects undertaken as part of this research program have a two-pronged effect in that they can inform basic scientific research on visual attention and visual memory and inform TD training and understanding for the Army.

The research topics particularly relevant to threat detection are organized into two complementary avenues of research: visual attention and visual memory. Within each avenue, there are at least three important TD skills that this research can inform, including attention-to-detail (attentiveness), detection and identification of non-lethal and lethal threat cues (recognition), and deterring and countering threats (action). These skills are essential for Soldiers in the OE within three core contexts of interaction: human: human, such as monitoring verbal and nonverbal communication for threat cues; human: terrain, such as scanning a landscape for indication of emplaced threats and human: computer, such as monitoring a computer display for indication of threats. Before describing the research, it is crucial to understand the OE in which the skills of TD will be applied.

Irregular Warfare Environment[1]

For dismounted Soldiers, the OE is particularly dynamic and unforgiving. Edwards (1962) used three characteristics to define a dynamic environment. Edwards was concerned with how persons create subjective probabilities of events. Though his description of a dynamic environment was developed to explain the decision environment in which subjective probabilities were considered, it accurately portrays an asymmetric, or more improbable, environment and the importance of the individual acting within it. The first is that a series of actions are completed across a given period of time in order to accomplish a task or attain a goal. Secondly, actions are interdependent; later situations depend on earlier actions. Finally, the environment changes independently, and often unpredictably, of the individuals within that environment, but also as a result of actions the individual takes. An asymmetric environment is full of activity (i.e., information and noise). Gibson (1986) emphasized the importance of not just what the observer brings to perception or just the information in the environment, but the importance of the observer-environment interaction. Understanding how Soldiers' presence and actions affects the dynamicity or informational complexity is important for fully understanding an irregular warfare environment.

Soldiers with recent deployment experience often note that the large amount of information and "noise" in an urban scene makes it extremely difficult to detect threats. This includes noise such as the amount of trash on a patrol route or the sheer number of people in a marketplace. Soldiers also note that the local populace knows what is going on, long before they do. Thus, being able to 'read' the crowd or understand the dynamics of the local culture is paramount for successful operations. However, being able to pick up the 'vibe' of a neighborhood does not just happen. Cultural understanding requires both a memory of important features and persons in the environment as well as continual vigilance while conducting operations. Though Soldiers may think they are simply relying on intuition, they are detecting and processing visual cues about the visual space they are operating in. There are two distinct options in which a threat can display itself: (a) Static Changes in Dynamic or Static Scenes - in this case changes have already occurred, but cues may be present that indicate threat while the visual space is full of other visual cues (dynamic) or relatively few (static) and (b) Dynamic Changes in Dynamic or Static Scenes - in this case the changes occur or are completed while the visual space is full of other visual cues (dynamic) or relatively few (static). A research program that examines visual attention and visual memory to address practical military problems must reflect the dynamics and complex nature of today's OE. The research should also examine the biases in human perception that make TD naturally difficult and are discussed in the next section.

Natural Processing Biases and Goals

Gibson (1986) stressed that the eyes never really fixate; they are always moving. This movement is an adaptive, involuntary behavior allowing more of a visual scene to be processed.

[1] Joint Publication 1-02 (August, 2009) defines "irregular warfare" as, **"**A violent struggle among state and non-state actors for legitimacy and influence over the relevant population(s). Irregular warfare favors indirect and asymmetric approaches, though it may employ the full range of military and other capacities, in order to erode an adversary's power, influence, and will." In the present document, asymmetric, irregular warfare, and dynamic environment are used interchangeably. See also Joint Operating Concept (2007) and JSOU Report 09-5.

However advantageous this adaptation may be, it certainly does not guarantee that we will successfully detect all the important changes in the environment. Consider the acts of concealment and misdirection in a magician's act. Magicians consider tricks to be successful by exploiting the satisficing efficiencies of our perceptual and higher order processing systems (Lehrer, 2009). An underlying concept that would benefit the three interactive contexts of human interaction and future research and training on threat detection is understanding how an environment can be manipulated to hide threats by taking advantage of natural human biases and innate processing mechanisms. For instance, Gestalt principles such as closure, proximity, and similarity serve as perceptual mechanisms used to make sense of the environment (Köhler, 1969). Similarly, the more salient features in a visual scene tend to capture our attention and anchor us to a certain point in the visual space. So, even though we are inherently equipped with adaptive mechanisms, such as saccadic eye movements, our information processing systems can still be taken advantage of.

In particular, research should examine how to improve the hit/miss ratio in TD. In a study examining the interaction of stimulus-to-rule matching and learning, Fisk and Lloyd (1988) concluded that participants always performed faster when the application involved a "positive" rule as opposed to application of a "negative" rule. A positive trial occurred when there was only one correct application (only one representative chess piece could move to a certain location). A negative trial occurred when none of the actual pieces could occupy a given target location. This remained true when the stimulus-rule mapping was consistent or inconsistent (inconsistent stimulus-to-rule mapping occurred when the stimulus matched a different rule on every trial). Since both search processes (positive and negative) were serial, the set size, or amount of stimuli available to search, had the most significant and direct impact on search time. If a Soldier is scanning an urban or rural environment, it may be a matter of how many items/objects must be scanned that will affect search time and identification of a target instead of the consistency that a particular stimulus will always evoke a certain response. The complexity of a given scene is an important independent variable that could be manipulated experimentally to increase understanding of the effects of learned rules on visual search and information load.

When a Soldier is visually scanning the environment, it is easier to make use of a confirmation strategy than a disconfirmation strategy. There is a bias to confirm that a rule is immediately applicable rather than to search more extensively and discover that none are, in fact, relevant. Visual scan may take the form of a serial process, which can be extremely fast and accurate or can lead to negative and costly outcomes. In a collection of information-gathering situations noted by Taleb (2007), looking for confirmatory evidence can placate our search for information so much so that we miss or simply do not recognize that extreme events will occur and will do so unpredictably. Seeking confirmation hints at an earlier suggestion by Johnson-Laird (1983) called the *principle-of-truth.* Johnson-Laird noted that we naturally seek evidence that confirms our (self-) generated hypotheses (i.e., schemas). More recent research concerning consistency reveals that the decision-making process is biased towards a 'leader' or preferred option resulting from the decision process (Russo, Carlson, Meloy, & Yong, 2008). Russo et al., also tested whether decisions between new alternatives are distorted by a need for reduction in effort, to amplify the mental space between alternatives, and/or to categorize information in

terms of consistency; they found maintaining consistency between potential choice contenders to be the most likely reason that new information would be used to support a preference that is already established. Thus, TD is not just a function of the environment, but also results from our innate information processing capacities and biases.

An important area of research on TD is examining how might an individual overcome inherent capacities and biases in visual perception. Though attention and perception are processes that often occur unconsciously and automatically, they can be driven by top-down influences, such as the goals of the observer. The tendency to "see what we want to see" typifies how goals influence visual attention and, even, visual memory. Thus, we may miss certain relevant cues in a visual space, because we are intent on locating only the desired object or person. One research topic worth studying is how goals drive bottom-up processes. For examples of goal-driven influences, see Simons and Levin (1998) and Simons and Chabris (1999).

A major learning point in the Marine's Combat Hunter Course is to be cognizant of natural biases in employment of our visual perceptual system (X-file, 3-35.3x). This includes the fact that we normally scan left-to-right because we are taught, for example, to read from left-to-right, as a result, we learn to scan in the same direction. The course teaches a right-to-left scan pattern to address this bias and is suggested to improve scan of the environment. The importance of relying on one's own eyes before utilizing an available technology is also emphasized. Assessment of natural biases and training to improve performance can be experimentally assessed to provide the most realistic factors to improve performance.

Three Interactive Contexts

Soldiers in today's OE must retrieve and process information from three primary contexts: human: human, human: terrain, and human: computer. In many ways, these contexts are interdependent, and an important research topic is whether or not skills from one context can be trained and transferred to another. For instance, how might monitoring a computer screen for threat warnings assist in detecting cues of potential threats in engagement with local citizens in urban settings?

Human: human

A great deal of current, non-combative operations involve interacting with the local population. A Soldier appropriately trained in TD would need to understand and give the appropriate amount of respect to the local populace and threat indicators that may be emplaced within that environment. Methods to counter insurgent TTPs are the non-combative measures that Soldiers employ to build a collaborative relationship with the local populace. Unfortunately, this level of interaction can often lead to frustration on the part of the Soldiers, even when all the seemingly appropriate steps are followed to establish a solid relationship with a local community (Bell, 2009). Nevertheless, a Soldier trained to detect visual threat cues in other humans will be better able to leverage relationships than a Soldier untrained or undertrained in TD. Being attentive and recognizing both verbal and non-verbal indicators of potential threat can lead to improved threat detection performance.

Human: terrain

The second interactive context relevant to TD is human: terrain. An important consideration is whether the type of terrain is urban or rural. Likewise, transfer effects as Soldiers move from one type to another is an operational concern and potential topic for research. One of the major characteristics of the Combat Hunter Course is understanding how an enemy might use a given terrain for concealment and protection (X-file 3-35.3x). A recent set of studies by Boot, Neider, and Kramer (2009) illustrated the importance of using camouflaged targets to study visual search and assess the effects of training for camouflaged targets. A similar line of research by Poiese, Spalek, and Lollo (2008) found that the similarity of a distractor with a target can influence whether distraction occurs as a result of stimulus-driven processing or goal-driven processing. Attentional capture by the distractor may depend on whether or not the distractor and target stimuli share defining features (i.e., same color) or whether their defining features are different (i.e., different orientations). Studying the effects of degraded stimuli, as suggested by Cockrell (1979) and also camouflaged targets (Brooks & Gillam, 2007; Poiese et al., 2008) should lead to better understanding of how targets are identified in natural settings. Likewise, as suggested by Boot et al., testing the effects of top-down processes versus bottom-up is a key topic to investigate for target detection research.

Human: computer

A third context in which Soldiers commonly learn about and assess their environment is human: computer interaction. Durlach, Kring, and Bowens (2008) specifically examined the visual interface for a situation awareness map. The background and findings of their studies are relevant for most research involving attention in a variety of visual spaces. Durlach et al., found that multiple, concomitant changes in the visual interface increased the time it took to respond to the changes. Further, the more changes that occurred the less likely all changes were detected. As set size increases, so too does difficulty in monitoring the amount of information and detecting change in it. How up-to-date these changes is certainly relevant for current operational tasks. For instance, if threats are posted on a monitoring system, but not removed once they become irrelevant, those icons simply become more information to sift through. Likewise, if the visual interface is updated by a higher-level of command, the end-users may not heed all warnings as relevant if they are thought to be outdated.

Thus, research on human: computer interaction, should include number and type of changes as well as level of control over the system. Durlach et al., further found reaction time for changes involving icons that disappeared was slower than for icons that appeared suggesting that cues in a visual interface that draw attention more automatically are more likely to be detected. Thus, detecting onset (appearance of an indicator) is likely easier than detecting offset (disappearance of an indicator). Likewise, the number of changes detected overall increased over the course of the experiment, indicating experience with the material alone may improve change detection ability. A research program that includes the manipulation of change in the visual interface will lead to increased understanding of how and when TD for visual interfaces is degraded. As Winn (1993) suggested, there are several steps persons may take when searching for information in graphical displays, such as extracting, discriminating, and judging the

usefulness of information. These concepts are especially true for understanding how information moves between unconscious and conscious processes. Winn particularly highlights the importance of interaction between both pre-attentive, and possibly uncontrollable, perceptual processes and later stage cognitive processes that can be controlled for information interpretation.

Visual Attention and Visual Memory

The interactive contexts discussed in the last section should be examined in relation to visual attention and visual memory. Visual attention requires the Soldier to vigilantly attend to a given environment, while visual memory requires a comparative process between the current visual scene and past visual scenes or experiences. An important consideration for developing a research program on TD includes: how memory affects attention, how attention affects memory, and whether they entail synchronous processes or the same process. It is important to make such distinctions, because they can inform what path research should take and where training should focus.

Memory affects attention. Not only is there evidence that memory is limited (Miller, 1956; Cowan, 2005), but also that attempting to remember certain objects in a previously encountered environment may be hindered by simply interacting with that environment again (Radvansky, 2008). This is particularly important for Soldiers patrolling the same route frequently who think they can easily notice something out of place. Likewise, the structure of a terrain environment can have an enormous effect on visual memory, such as influencing a Soldier's ability to update their representation of a dynamic situation. For instance, humans are good at processing their current representation of an environment, especially spatial location of objects. Radvansky notes, however, when objects from previously encountered spaces move from previously relevant to currently irrelevant and vice versa, errors are likely to occur. Also, when navigating a building and moving from one room to another (i.e., a spatial shift) memory errors can occur because of the amount of mental resources needed and the coordination of processes, such as moving information to and from working memory. The more spatial shifts required, the more likely memory will be disrupted, even for information that is applicable to the person's goals. A final finding from Radvansky's research is that knowledge of objects in a visual space, which have been interacted with previously, may not be as available to memory simply by navigating through that same space again. This is a relevant, and counterintuitive finding, particularly so for Soldiers navigating on the ground or through buildings. A certain complacency may result if a route or building has been traversed numerous times, so moving through that space again may actually be degrading TD. Determining when and how to counter complacency is an excellent research path for TD.

Attention affects memory. The goals of the observer are also likely to drive memory search. Previous research in target identification (Cockrell, 1979) revealed that a basic psychological principle such as overshadowing can influence the ability to effectively identify various targets. Depending on the intent of the observer, certain cues may receive more attention, while others may be missed. Overshadowing occurs when a salient feature of a target captures attention, while the remaining target features go unnoticed or unprocessed; the dominant feature 'overshadows' the other features. In this case, the bottom-up feature drives a memory search for

a relevant target. Cockrell took this principle and integrated it into a research/training format to examine how Soldiers might perceive targets in a real setting. By using degraded targets or by showing only a portion of the target stimuli, this was a more realistic reflection of how Soldiers would encounter targets in actual operations. In the context of threat detection, however, the target can take the form of multiple cues within a complex environment. For instance, on a dismounted patrol, Soldiers may need to be aware of any cues that might directly indicate a lethal threat, such as certain persons staring intently at an approaching U.S. patrol. But, sometimes multiple cues may be necessary for Soldiers to feel an environment is threatening. However, on mounted patrols, the pace of interaction is much faster and important cues may involve the behavior of approaching vehicles and well-concealed static threats in a dynamic environment (i.e., IEDs). Further, when interacting with local nationals, via an interpreter, both verbal and non-verbal gestures may serve as cues indicating a potentially lethal situation. In this line of research, regardless of observer intent, salient features may drive what Soldiers attend to and, thus, what they find most important about our environment.

Whether attention and memory involve the same cognitive process or different processes was explored by Engle (2002). Engle's findings suggest that attention or the executive function and working memory actually entail the same mental process. Engle and colleagues have also explored the importance of individual differences in general measures of working-memory capacity and how this affects control of visual search tasks (Kane, Poole, Tuholski, & Engle, 2006). Further research might assist in determining what processes are needed for TD and how these might manifest in the required skill sets.

Attentiveness, Recognition, and Action: Three Foundational and Trainable Skills

As noted, there are three skills that TD research should investigate including: attentiveness, recognition, and action. Attentiveness involves basic perception, recognition involves higher-level processing (understanding a threat is present and its level of importance), and action involves deciding what to do with that information. This selection of skills should be the primary focus of the proposed TD research. Although, there may be other skills involved in TD, (see Kowalksi-Trakofler & Barrett, 2003 as an example), the attentiveness-recognition-action skill set was selected based on reviewed research, including comprehensive research (Cowan, 1998; Cowan, 2005), highly influential work (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977), and current doctrine (X-file 3-35.3x; see also Army 7 series collection). These skills make up part of an iterative process to identify and mitigate threats.

Attentiveness

Attending to a situation, including the objects and persons embedded within it does not guarantee that we will be able to extract the desired and useful information. An example is a study conducted by Simons and Levin (1998) where pedestrians were largely unaware that a person asking for directions was switched with another person after a short distraction (two workers carrying a door between the researcher and participant). Most participants did not notice the change. At least two important results from this study relate to threat detection. One is that we do not necessarily maintain a detailed representation of the world from one moment to the next. Thus, research examining whether and when we maintain a detailed mental picture of

our world or a just-in-time model, based on only salient information, could increase our understanding of TD and training. The second result pertains especially to human: human interaction and perceived similarity. How one identifies with a social group or individual, such as students identify more readily with a younger cohort than senior citizens, appears to make a difference in how well we attend to the interaction and the visual surroundings.

The ability to detect change was examined by Simons and Chabris (1999). When persons were asked to watch a video and count how many passes a basketball team made in a given time. Most participants failed to notice that a gorilla appears in the middle of the screen, beats its chest, and then wanders off. Though the gorilla was clearly in the foveal field of view, the results indicated that directed attention, masks changes in unattended aspects of a situation. These and related results (Rensink, O'Regan, & Clark, 1997a; see also Simons, 2000) indicated that detection, including TD requires visual and mental attention and changes are less likely to be detected that are not in our "center of interest" or those that are in our periphery or "marginal interest." Further, task interruption can have a major impact on attention and memory resources and the ability to maintain goal-oriented performance (Li, Blandford, Cairns, & Young, 2008; Monk, Trafton, & Boehm-Davis, 2008; Ratwani & Trafton, 2008; Rensink, O'Regan, & Clark, 1997b).

Recognition

Recognition skills rely on two primary processes: familiarity and recollection. However, the exact definitions of what these processes entail and whether they are parallel or serial functions remains an ongoing debate (Mandler, 2008). Mandler (1979) suggested that two important mechanisms essential to understanding recognition are integration and elaboration. Integration is linked with pattern-matching, such as knowing what events designate a ball game is taking place, and is based on simple frequency and recency of exposure. Elaboration, however, involves a more detailed store of information such that one would know a ball game involves a particular team. Thus, if a quick pattern-match cannot be achieved (as in the integrative process), a lengthier elaborative memory search is carried out to identify a target match. For TD purposes, recognition moves beyond basic processes and also includes an understanding component. Thus, recognition is defined as a familiar or recollective process leading to an interpretive conscious experience revealing a potential threat is present. In terms of the visual attention processing pathway, the Soldier should know that something attended is important or out of place in the visual space, a cue that indicates potential threat. Following the visual memory path, understanding that the change or cue is similar to one that was experienced on a previous patrol is important and requires action.

Another important aspect of recognition research that Mandler (2008) notes is the broadening of empirical evidence in natural settings, where memories are organically embedded in a rich context (as typically opposed to a laboratory setting), can help explain the mechanisms important for recognition. Understanding recognition processes is important for training purposes, because these processes determine how recognition is likely to be carried out (i.e., what processes are needed for recognition) and whether an observer can detect that a change has occurred or will occur in a given environment. For TD, recognition is knowing that a change or

cue in the visual environment is important for changing a non-threatening environment to a threatening one.

Action

In guerilla warfare environments, the threats are deliberately and intentionally well-concealed. Often concealment is about misdirection or deceptions taken by threat agents. Soldiers are required to be attentive to threat and to be able to recognize how various threats change the battlespace and battle rhythm. Nevertheless, Soldiers are strained to detect threats before they attack. When attention is manipulated, uncertainty is likewise affected (Smith & Ratcliff, 2009). Thus action is not only about reactive responses to threat; it is also very much about what decisions Soldiers need to make to reduce the risk of threat by utilizing attentiveness and recognition processes.

Once a target is recognized, the next step is to decide the correct action to take. Again, understanding the observer-environment relationship (Gibson, 1986) is a fundamental skill for the OE. Soldiers need to be aware of the complexity of their environment, yet not be hypersensitive such that every potential cue leads to a false alarm. Action for both information processing pathways is knowing what to do as a result of recognition. In either situation, the Soldier has to be able to execute appropriate action in response to either visual recognition of a potential indirect indicator or direct indicator of threat, react to a mismatch between memory and the current visual environment or a combination of both. Action is a decision-making process. A research program that takes into account how attentiveness and recognition influence that decision process could greatly inform TD. Likewise, understanding how Soldiers manage uncertainty (Smith & Ratcliff, 2009), perceive degraded stimuli (Cockrell, 1979), and deal with their own processing biases (X-file, 3-35.3x) is imperative.

Attentiveness, recognition, and action are the primary skills necessary for TD. TD is not simply about noticing that something has changed, but it is also requisite that the observer knows how to proceed with the newly updated view of the current environment. For instance, if a Soldier on patrol notices that there are fewer persons occupying a particular location within an open market, the Soldier must compare various bits of information of why this may be the case (i.e., perhaps it is prayer time or there could be a real threat present). Thus, the three components of threat detection can be summed up as follows. Attentiveness involves being in a psychological and physiological state that facilitates detecting that something(s) in the environment is potentially threatening. Recognition involves understanding the importance of the change or detection of the cue. Action is knowing what behavior to perform as a result of detecting and understanding the change. J.J. Gibson (1986) emphasized the key to understanding perception is to understand and research the interconnectedness of the observer and the environment as one system rather than as separate components. Soldiers must understand they are part of the environment, not just observers or reactors to it. This provides a more powerful research and training approach, yet also less traditional. In the past, Soldiers were usually trained to treat the environment as something they control and react to rather than understanding themselves being a functional part of (X-file, 3-35.3x). The Marine Combat Hunter Course, for instance, is a course where the training has changed the Soldier focus from reacting to an environment to appreciating and shaping it.

Relevant Theories

This section briefly reviews three well-established research theories that would facilitate research on the topic of threat detection: ACT-R, Signal Detection Theory, and the Recognition-Primed Decision Making model.

ACT – R Theory (Skill Acquisition and Deliberate Practice)

A commonly cited theory of skill acquisition is that proposed by Anderson (1976; 1982; 1983) called ACT or Adaptive Control of Thought (and later ACT-R, 'R' standing for Rational) based on the initial work of Fitts (1964). ACT-R is proposed as a cognitive architecture to account for how the human mind functions to include visual, motor, and memory processes. The primary components are the modules, the buffers, and a pattern-matcher. There are two types of modules, one for perceptual-motor and one for memory (which has two sub-components, procedural and declarative memory). The perceptual-motor module allows for basic interaction with the environment. The declarative memory module provides memory for facts, while the procedural provides scripts on how to perform. Through buffers or conduits, the architecture accesses the information in the modules. The pattern-matcher performs a search that attempts to match a production with what is contained in the buffers. When the production or rule is executed, the information in the buffers can be changed as can be the system overall. According to this model, the way cognition works is via the execution of a number of production firings or rule executions.

ACT-R is relevant for research on and training of the skills of visual attention and visual memory, because it provides a theoretical framework and methods to examine their application. All the skills proposed, attentiveness, recognition, and action can be described, theoretically, by the ACT-R framework. For instance, a study by Lyon, Gunzelmann, and Gluck (2008) illustrated that an ACT-R model was good at accounting for limitations in visualization capacity, particularly associative interference and decay. Although Lyon et al., were concerned with persons turning verbal instructions into mental representations, they concluded that the act of visualizing has several, general effects on behavior. For instance, they note that generating a mental space appears to be treated by the user as a real space and that the spatial proximity generated mentally has direct effects on subsequent performance.

Approximately 10,000 hours with a task is needed to produce expert performance according to deliberate practice theory (Ericsson, Krampe, & Tesch-Romer, 1993). Although the length of time needed to acquire a particular skill may vary and what processes need to take place to actually acquire the skill are debated, it is commonly agreed upon that time spent on the task is the prominent cause of whether or not the skill will be acquired (Anderson & Schunn, 2000). Likewise, Ericsson et al., importantly noted that deliberate practice is both highly structured and the performer knows that the explicit objective is to improve performance. Regardless of academic debates, researchers at ARI have been successful at implementing principles that have come out of work on skill acquisition and deliberate practice (Shadrick, Crabb, Lussier, & Burke, 2007; Shadrick & Lussier, 2004; Shadrick & Lussier, 2009). The eight principles developed by Ericcson et al. and used by Shadrick and Lussier (2004) such as repetition, focused feedback, and conscious focus are applicable to further research and to

training on attentiveness, recognition, and action, discussed further in the *Training Issues and Approaches* section.

Signal Detection Theory

Change detection is primarily studied as a phenomenon where participants are asked to determine whether or not something has changed in a visual scene. However, the ability of threat detection involves attending not only to changes in the visual space, but also recognizing and acting on indicators of change or cues that imply a potentially threatening situation. Thus, not just noticing a change or cue, but also knowing the cue is potentially life threatening, is a key difference.

Signal detection in a dynamic, visual environment where threats vary in type and frequency within the same deployment is quite difficult. It is layered by the complexity that requires a Soldier to function in the three contexts, human: human, human: terrain, and human: computer in an operational environment full of uncertainty. Further threat detection is certainly more complicated than basic signal detection, because threats have been emplaced so as not to be detected until their impact can be executed. The tactics, techniques, and procedures (TTPs) employed by asymmetric fighters resemble those used by magicians, such as inattentional blindness (Macknik et al., 2008). Taleb's overview (2007) on how we go about sampling information from our environment from a certain perspective brings up an important point that affects attentiveness, recognition, and action for the individual Soldier. There are only so many avenues which events may take and exposure to events and the paths they take should update understanding and expectations of the distribution from which we are sampling.

Soldiers have to understand that the operational environment they are visually scanning and, thus, sampling from is not normal in nature. To explain, we naturally gather frequency information as a result of normal interaction with our environment (Gigerenzer & Todd, 1999). This interaction leads us to expect events to occur at a certain rate. Unfortunately, in a dynamic environment, the absence of an event is coded as such, but this coding leads to a complacency that the event is not occurring (or that conditions were not met for the event to occur). Tasks, such as threat detection require reliance on a mindset that puts as much value on the absence of evidence as it does on the evidence of absence. Thus, a research program taking a signal detection approach could evaluate effects of TD by manipulating the signal to noise ratio present in the environment.

There are, at least, four possibilities from which a Soldier on patrol will gather information and, thus, develop a model of what s/he will likely encounter on patrol: (1) of the times I have been out on patrol, nothing has happened (no threat detection equals no threat), (2) of the times I have been out on patrol, we have detected threats X number of times and successfully engaged them, (3) of the times I have been out on patrol we have failed to detect a threat that caused a certain amount of damage (or been detected but no damage) or (4) of the times I have been out on patrol, we mistakenly identified a false threat. These possibilities were originally proposed in signal detection theory (Green & Swets, 1966) and are denoted as: *correct rejection, hit, miss, and false alarm*. See Figure 1.

	Observer Responds "Yes"	Observer Responds "No"
Target Present	Hit	Miss
Target Absent	False Alarm	Correct Rejection

Figure 1. Four possibilities from a signal detection framework.

Signal detection theory was developed as a means to discriminate actual ability from fluctuations in internal motivations. As a Soldier's exposure or sampling distribution changes, his/her expectations will also adjust, but not necessarily in a linear or 1:1 fashion. If on patrol and an improvised explosive device (IED) explodes, a Soldier's expectations for the occurrence on subsequent patrols, at least for the near future, may be erroneously over-weighted; s/he will likely commit more false alarms than is warranted by the environment, and understandably so. Thus, that Soldier's model of a potential situation is inadequate, because the distribution of expectation is shifted in an ineffective manner. Using signal detection terms (Green & Swets, 1966), you do not want to be so biased that you think everything is a threat; you want your "sensitivity" to appropriate cues or *d'* to be functional for the situation.

In contrast, a failure to detect may lead to a more complacent strategy in the future. However, a fifth possibility not noted above is: of the times I have been on patrol, nothing happened, but, unbeknownst to me, it should have or could have (an IED failed to detonate or at the last moment, the insurgent decided not to attack). This is a melding of possibilities 1 and 3 noted above. Unfortunately, this possibility is difficult to factor into one's expectations, because the evidence that produces it does not readily reveal itself to the observer. Likewise, it is easier for us to confirm hypotheses than disconfirm them and also easier to search for evidence to continually support our confirmation. As noted before, the absence of evidence (no threat detected) is not necessarily evidence of absence (there are no threats here in my AO).

What also makes current operations especially difficult to train for is the third (and fifth) possibility. IEDs can take almost any form. Chisholm (2005), citing the Force Protection Working Group, noted that IEDs have been found in garbage bags, milk cartons, meal-ready-to-eat (MRE) bags, potholes covered over with dirt, and cars faking problems to list only a few. This makes TD an essential ability for operating in this environment, yet difficult to prepare for.

Though they did not examine visual threat detection, Brown and Steyvers (2009) did provide some insights into human information processes involving the detection of changes in information sets, particularly tracking changes of hidden states. They aptly concluded that persons naturally create inferences about past states of the world and commonly have problems when trying to predict future states of the world. This research supported that of Jones and Pashler (2007) who noted that the human mind is innately structured to be forward-looking, yet we still often have trouble predicting future events in a number of contexts. Given that visual threat detection requires predicting future conditions of the visual environment, persons may be naturally prone to make errors of this kind.

As noted Durlach et al.'s focused research on computer displays can improve design of visual interfaces, but Soldiers in the current dynamic environment must gather and comprehend information from the local population, terrain, and computer-based systems. Unlike, interacting with a computer display, such as a Unmanned Aerial Vehicle operator does, dismounted Soldiers are acting on and being reacted to by others in their environment directly. Thus, dismounted Soldier's actions have more immediate impacts on their environment. Unlike searching for dynamic changes in a visual display, dismounted Soldiers may have to detect cues and/or changes to their environment that are static, but against a dynamic background. Thus, one of the most important skills that a dismounted Soldier needs to learn is to detect the presence of a relevant non-dynamic information object that has been changed (i.e., noticing fresh or churned dirt), imbedded within other changing non-relevant cues (i.e., a busy intersection that is constantly being changed by the presence and absence of different people and vehicles). Durlach et al., also note that the consequence of detecting change (i.e., in a lab experiment vs. in actual operational conditions), the level of experience an individual has with a particular operational environment, and the context of a laboratory environment vs. a field setting are important factors to consider when studying change detection and similar phenomenon.

Given the skills noted above and the signal detection framework, how might TD occur? Initially, the Soldier must be attending to available information within the visual scene (either consciously or at some unconscious level) and this information must, most likely, be the center of interest. Simons (2000) notes that changes in the peripheral zone or those of marginal interest to the observer are more difficult to detect. Simons notes this occurs even under the "intentional" methodologies (the observer knows the task is to detect change, but seldom does when the change is in the marginal zones). Likewise, this refers to detection of change, not motion (to which the peripheral field of vision is particularly sensitive). A pattern-matching process may initially occur alerting the Soldier that something is different. However, detecting something is missing is a more difficult process than detecting something has been added to a scene (Rensink, 2000). Recognizing the change then requires a comparison initiated by an inquisition process, such as why (i.e., is there a change and what does it mean?). For instance, if this is the Soldier's normal patrol route, s/he must take into account cultural aspects (such as, is this time nearing a period of prayer in this Muslim community, which may draw persons to a nearby mosque) as well as tactical aspects (such as, does the local populace know that something is going on in this area and have cleared out as a caution) to name a few. As a result of this cue/change detection, the Solider must evaluate potential actions that will lead to the best possible outcome (send Soldiers to gather information from locals, act by not reacting to the change, to draw the enemy out, request to perform a cordon and search of homes in that area, etc).

In sum, our expectations about the likelihood that events will occur can affect how sensitive we are to those cues and changes related to those events. For instance, exposure to numerous IEDs on initial patrols leads to an expectancy of IED events in the same area again and this expectation may spill over into other (AOs). Likewise, considering research and training that fools the mindful human observer (Macknik et al., 2008) is likely to yield influential results for better understanding threat detection. A research program that incorporates an understanding of how to test and fool the human perceptual system, specifically the visual, will do a great deal to inform TD by exposing gaps in our information processing system.

Recognition-Primed Decision Model

In a review of ‘natural’ decision-making situations, Klein and colleagues (2003) noted four factors that can make problem detection difficult. The first is that some warnings have a gradual onset, which makes them more difficult to detect. Secondly, some cues are simply more subtle and require greater attentiveness in order to detect them. Third, they noted that experience can be an important factor in guiding whether or not multiple and/or seemingly disparate pieces of information will be put together to form a coherent picture of the situation. The fourth factor they noted was if an individual becomes too complacent, warnings will go unheeded; as Taleb (2007) notes, *black swans* or unpredicted events with enough strength to evoke a large change a given environment, may go completely unnoticed. The specific barriers to problem detection they concluded were, when an error is committed, we are more likely to assign blame only to one source rather than to accurately assess each source as a potential cause. This can distort our memory or representations. A second barrier occurs when a background is noisy, it is more difficult to sift through the environment and home in on the cause; both our attention and memory have limited capacities. The third obstacle, occurs when an inefficient method of data collection is taking place, such as looking for the wrong cues. The factors and the barriers both serve as potential variables to manipulate.

Interviewing persons about time-pressured situations may not reflect they actually knew that they knew something in a situation was amiss. The reason for this is that much of information processing, from the very basic sensory input (i.e., visual input) to very complex (i.e., recognizing which house to search for potential insurgents) is done by the unconscious. At the expert level, these processes become less conscious. Obviously, this frees up a great amount of resource for processing information at a conscious level, but leaves the user of that information, and those interested in discovering what information was utilized, in a difficult situation to understand what happened; one may not be able to readily describe what information was used nor why (Ericsson & Simon, 1993). Klein’s (1998) Recognition-Primed Decision (RPD) model aids in accounting for how persons could react, especially in situations of time-pressure, with very accurate and optimal strategies, as opposed to slowly evaluating many alternatives and options which may or may not work. Klein notes that, mainly through repeated experience, persons are able to develop quick, intuitive reactions to situations. This, of course, is a characteristic of deliberate practice in the sense that deliberate practice leads to less conscious behavior or learned reactions to stimuli. A recent adaption of Klein’s original model, demonstrates its flexibility to incorporate other interpretations (Mueller, 2009). Mueller meshed the Bayesian framework for making decisions with Klein’s model and provides a revised framework to account for how experts make decisions using available information, probability of event occurrence, and reliability of the information source.

Expertise

The frameworks discussed above each lend themselves to a better understanding of all skills. The frameworks also provide a foundation for a better understanding of each particular skill such that signal detection provides a basis for studying attentiveness, ACT-R for studying recognition, and RPD for studying action. The ultimate level of performance or endstate is to develop expertise in a domain and these frameworks can assist in understanding the development

of expertise for each skill. Recent research has indicated that studying sports from a psychological perspective can inform the military, because they share a number of characteristics (Williams, Ericsson, Ward, & Eccles, 2009).

A major element of using findings and results from sport psychology to assist in studying military contexts is to understand the importance that emotion plays in dynamic and, especially, uncertain contexts. One of the purposes of the current research effort is to understand the components of TD at the expert level and develop a model of expert TD that can guide future research and training. The results of employing various experimental approaches will be to create a wealth of materials for future experimentation that will advance the basic understanding of the characteristics of threat detection and also increase the Army's understanding of training the skills necessary for establishing superior threat detection ability. The next section explores both training issues faced by today's Army as well as approaches and methods for training threat detection.

A dynamic threat environment is an anxiety-producing one. Regardless of level of preparation, the emotional strain will push the limits of any Soldier (Grossman, 1996; Grossman & Christensen, 2008). As anxiety increases, shifts or alterations in visual attention occur. For example, what happens when drivers are required to navigate a simulated racecourse while detecting the relevance of cues presented in their peripheral visual field under various levels of anxiety? As levels of anxiety increase, detection speed of peripheral cues decreases, as well as overall driving performance (Janelle & Hatfield, 2008). Such effects were attributed to a ineffective narrowing of attention and an increase in inefficient search strategies when drivers became anxious. Related research examined the "quiet eye" period which is the time between final fixation on a target and initiation of the motor response. A longer quiet eye period characterizes expert performance in a number of self- and externally-paced sports, including billiards and free throw shooting (Janelle & Hatfield, 2008). These researchers discuss how the quiet eye period may reflect the organization of neural networks involved with the orienting and control of visual attention, or possibly other compensatory behaviors such as emotion regulation. They conclude that future research on attention and anxiety should also examine development of the "emotional expert."

Overall, attaining the skills of threat detection -- attentiveness, recognition, and action -- will allow Soldiers to detect and understand meaningful changes to the visual space. Thus, expert threat detection is defined as detecting, understanding, and acting on a change in the meaning of a visual scene, specifically changes (or cues) in a scene that shift the environment from non-threatening to threatening. Before a research and training program can be established, a number of current limitations must be recognized. Limitations of current Army training issues and potential approaches to overcome these limitations to improve TD performance will be addressed in the next section.

Training Issues and Approaches

The overarching competency of threat detection is the ability to comprehend, control, and manipulate the visual space including any threats, while understanding one's role within that visual space. Soldiers must be able to detect, evaluate, and defeat threats in an operational

setting. The two primary research paths, visual attention and visual memory, also serve as the primary avenues for training threat detection skills. By training TD skills, including attentiveness, recognition, and action, the five training objectives can be achieved to include, reduction in errors, increase in performance speed, increase in flexibility to novel problems, increase in robustness to unexpected events, and increase in skill retention. The key for meeting these objectives is to take deployment experiences from Soldiers and formulate them into meaningful training full of information that Soldiers can remember and utilize resulting in improved performance.

Effectively training TD is part of an ongoing objective which various military agencies are attempting to achieve. For instance, in July 2008, the Army Research Laboratory, presented a call for development of technology that can disable IEDs at a distance, both from a vehicle and from on foot. Recently, Livingston, Brown, Julier, and Schmidt (2006) have researched the technical side of situation awareness through development of a mobile augmented reality apparatus; the purpose of this device is to allow real-time information of Soldiers and the environment to be transmitted to the planning and coordinating element of a mission. Likewise, Savick, Elliott, Zubal, and Stachowiack (2008), in an attempt to reduce workload and decrease response time in tasks requiring a high visual workload explored manipulations of representations of auditory, visual, and tactile information, with mixed results.

Despite the interest in maintaining TD skills, a number of issues present themselves due largely to the current operational tempo and Army Force Generation (ARFORGEN) process. These stem from two main issues, lack of time and lack of resources, but envelopes the following: a lack of personnel for necessary slots, lack of time to train, lack of time on equipment, unavailability of resources, lack of monitoring skill retention, and lack of time with a unit. However, TD skills are trainable in garrison or down range, whether all personnel and resources are available or not, and can be laid over existing training of basic Soldier skills, such as weapons qualification. Thus, threat detection lends itself well to “hip-pocket” training, such that Soldiers almost anywhere can take time to test and reinforce TD skills. For example, Soldiers performing physical training might incorporate attentiveness, recognition, and action during physical training. This might include, pre-staged targets that Soldiers would need to detect while running their route and report at the end of a run.

Training can be broken into two primary avenues of approach: institutional-focused and unit-focused. Institutional in terms of schools and field manuals are excellent forms for storing and transferring knowledge across the Army. Unfortunately, the time to translate more recent knowledge and experience into institutionally-based instructional materials sometimes fails to meet the pace of operations (Dubik, 2009). Units in theatre need a quicker trigger for taking lessons learned and turning them into training Soldiers can apply to the operational environments they are in.

Likewise, though Soldiers from deployments have a wealth of knowledge and experience about conducting operations in respective environments, they may not always have the resources to turn those experiences into training products that can be used at a later date. There simply is not time during operations to step back and reflect on what might serve as effective training for new and old Soldiers once back in garrison. Platoon leaders, for instance have a number of

reports concerning operations that must be submitted to higher levels of command. However, understanding how the mass of information from the battlefield might be used to assist in developing a training program is, understandably, not an immediate priority.

Based on recent interviews, Soldiers with recent deployment experience unanimously noted that more training on the tasks that would be conducted down range and more realistic training would have been helpful prior to deployment. They also noted that accomplishing training at home station would be the best use of time and resources. Since TD skills can be overlaid with extant training or conducted in sync with other training and exercises, it lends itself well to home station training and utilization of resources available at home station. For instance, Military Operations on Urban Terrain (MOUT) sites that include live, interactive training scenarios with role players, addresses training the skills needed for the human: human interactive context, a major issue for both combative and non-combative operations.

As noted previously, dealing with uncertainty and a dynamic environment can be difficult to grasp and also train for. The "7 Series" collection of field manuals published by the Army, provides guidance for training basic infantry skills. These documents also repeatedly note the difficulty of dealing with and training for uncertainty. For instance, FM 3-21.8, *The Infantry Rifle Platoon and Squad,* reads, "There is no such thing as perfect awareness or understanding of a situation" (pg. 1-6). A goal of this project is to capitalize on such training already available and improve upon Soldiers' understanding of the uncertain environment, recognizing perfection may not be attainable.

A philosophy that can address institutional, and unit training needs is not an easy task, but likely the best candidate for addressing, not only skills needed for the OE such as threat detection, but also a majority of skills needed for a variety of operations. This can be initiated by identifying and prioritizing threat detection tasks and methods necessary to operate effectively in the OE. The following sites serve as culminary sources of information on many tasks and skills, including TD: Center for Army Lessons Learned (CALL), Battle Command Knowledge System (BCKS), Knowledge and Information Fusion Exchange (KnIFE), Joint Improvised Explosive Device Defeat Organization (JIEDDO), and the recently launched Army Training Network (ATN), and courses such as the Marine's Combat Hunter Course. Though not comprehensive, all are mechanisms that attempt to provide more recent information quicker than doctrinal updates.

The eventual goal of training is to develop Soldier skills to the highest performance level possible. Coupling information gathered from such resources and the experience of Soldiers with studies on expertise presents a viable solution to meet training needs. For example, Staszewski (1999; see also Staszewski, J. J., & Davison, A., 2000) based a very successful land-mine training program on an information-processing analysis of the land-mine detection skills demonstrated by one 30-year veteran of land-mine detection and clearance operations. A primary goal of courses that train "expert" behavior is to capture the essence of expertise in threat detection in order to cognitively engineer training methods to best benefit the student. An example of developing a framework of expertise includes the three stages identified by Williams et al., (2008): observe the expert's performance to develop a representative task where component skills can be reproduced and simulated under controlled conditions, identify the

mediating mechanisms of superior performance using process-tracing measures (e.g., verbal protocol analysis, eye movement recording), and identify how these mechanisms are acquired during skill development so that implications for practice and instruction may be identified. Further, a valid expert model should address key research and training issues, such as: What is superior (i.e., expert) performance? What skills and characteristics enable expert performance? How best to train expert skills? Model development and validation is an iterative process which requires a mix of novice, intermediate, and expert performance in threat detection in the OE.

An important, but often overlooked component of training programs is measurement of performance. Validity issues include what constitutes a threat, the range of representative threat types addressed, threat and setting realism, threat levels, and differences in threat detection performance between Soldiers, including at varying levels, novice, intermediate, and expert performers. Likewise, if the desired end state is to produce more expert/proficient performance how best to develop threat detection skills and assess those skills as they develop, are essential objectives to achieve. A good understanding of development of more expert-like behavior, that is essential for good training development, requires measurement that adjusts to and tracks varying levels of performance accordingly, from novice through expert.

The emphasis of designing threat detection training should be on patrols, reconnaissance, and convoy operations. The training should address the detection of animate and inanimate threats. Training designed to include an array of multi-media formats that range from computer-based delivery to field-expedient training methods (e.g., simulation/animation, live video, photos, and textual/graphic hard copy) will be able to take advantage of the focus the different methods offer. Training materials and scenarios might include introductory information, training objectives, and rapid manipulation of threat variables to include number, type, and detectability with an emphasis on developing expert performance.

Visual Attention

Attentiveness in the visual attention pathway, or attending to the visual space so as to detect potential indicators of a threat, is the first necessary skill to learn. This requires a familiarity with what animate and inanimate objects might serve as threats. Unfortunately, there is a wide variety of indicators that could serve as a threat device (i.e., anything from roadside trash to a vehicle or person). Likewise, promoting the idea that a Soldier is not just reacting to his/her environment, but also that s/he can influence the environment through action or inaction should prove beneficial. Understanding the environment is full of information and that the individual Soldier is also emitting information through action and inaction is globally informative. For instance, an insurgent interested in hastily implanting an IED, will be very interested in understanding what Soldiers within the approximate area are doing. Their behavior, whatever that may be, is information that can be exploited by the insurgent.

Recognition is understanding that the meaning of a visual space has importantly changed. For instance, recognizing that some newly patched concrete along a sidewalk could change the meaning of the visual space, because it could indicate a hidden IED. Thus, this changes a normal scene to a threatening one. Recognition acts as a transitional and integrative mechanism between perceptual processes that have detected cues and the action step or decision making processes.

Action in the above case is appropriately reacting to this information. For instance, if a newly patched sidewalk seems out of place, then the Soldier needs to call attention to the squad. For Soldiers conducting missions in the current operational environment, it is not simply about detecting change, but also about managing change. For instance, detecting change requires a certain level of training, but processing that information requires going a level up from that. Detecting threats or warning signs that may materialize into a threat is not always sufficient. What the Soldier does with that information is key to obtaining mission objectives. Soldiers with recent deployment experience to Iraq note that the amount of noise in a scene is extremely difficult to manage. The local populace knows what's going on before the Soldiers do; thus, reading the crowd is key. Therefore, making decisions about what information is worth further processing is fundamental to functioning in an asymmetric environment.

Visual Memory

Attentiveness along the visual memory pathway is process or set of processes for accessing memories that will provide beneficial information for the task at hand. Although no patrol route is the same, even from day to day, Soldiers can become better at cataloguing events that will be useful later. For training purposes, salient and varied examples need to be provided. While also visually scanning the environment, memory needs to be an asset that the Soldier can utilize when necessary.

Recognition is understanding that a cue matches a threat indicator from a previous experience. Through practice and guided experience, Soldiers will become familiar with features of a situation that initiates appropriate action. However, training is more difficult than simply providing memorable examples. The skill of recognition is effectively trained when salient and beneficial examples are recalled without interference from internal or external distracters.

Action in the above case is appropriately reacting to this information. For instance, if this newly patched sidewalk was not there on the last patrol or triggers a memory of an IED buried in concrete from a previous patrol, the Soldier needs to react accordingly. If the Soldier is on patrol, then s/he needs to call attention to the squad.

Training Objectives

There are five TD training objectives. These were adapted from the brief review and assessment of skill acquisition models (Taatgen, Huss, Dickison, & Anderson, 2008). The first of these is a reduction of errors. A reduction of error occurs at the attentiveness step not only when more threats are detected, but when detection performance is maintained so that the available possibilities, hit, miss, correct rejection, and false alarm, as indicated in the *Signal Detection Theory* section, are indicated within an acceptable margin of error; in other words, perfect calibration at this task may not always be possible. Performance achievement has to be assessed at the optimal level that is possible, not necessarily the optimal level desired.

A reduction in errors may also occur at the second step of threat detection, recognition. At this step, the observer has to understand what the change means. Thus, whether a threat is detected at the attentiveness step is irrelevant if the observer does not recognize its importance.

Finally, at the third step, the observer must decide what action is necessary as a result of a recognized cue. Even when change is attended and recognized as task relevant, failure to execute the correct behavior(s) will still lead to overall error.

A second objective is to increase performance speed so that threat detection occurs more rapidly, while maintaining accurate performance. Although execution speed may vary at each of the three skills, a reduction in the amount of time it takes to carry each of them out is indication that performance has improved. Although attended change may occur rapidly (a few seconds or less), recognition could take longer, and action, since it may require a number of moving parts and communication between them (Soldiers communicating and maneuvering as a squad), may take much longer than either of the other two processes.

The third objective is to increase flexibility of those skills. Increasing flexibility in those skills means that they can be adapted to different environments, which may not have been experienced during training. Thus, when a novel situation is encountered, the training will readily transfer to this new environment with minimal to no impairment of performance. For the attentiveness step, a Soldier exhibiting good flexibility will be able to attend to the relevant cues across situations (i.e., whether a patrol route is the same one or whether it is a new route). Being flexible at the recognition step means that a Soldier can be embedded in an old or new situation and recognize when a situation's meaning has changed so as to affect task relevance. The action step in threat detection may vary with the situation. For instance, a patrol along a route containing buildings constructed in very close proximity to one another would limit maneuverability, while a patrol along an open highway would allow greater maneuverability, but less cover. Therefore, the action step would require an understanding that different threats may be present in different locations and decisions need to be executed as required by the situation.

The fourth objective is to increase the robustness of these skills. Robustness for this training means that the acquired skills will be maintained in an environment where there is a high likelihood that disruptions of execution of these skills will occur. At the attentiveness step, even if there are distracters (irrelevant visual noise) and other task-relevant requirements that add to cognitive load, the Soldier still has to be able to attend enough to a scene to notice that something meaningful has changed or that threat indicators are present. Likewise, despite this noise, the noticed change has to be effectively processed so that the change in meaning of a scene is understood. Finally, in lieu of other irrelevant and relevant information (for other tasks), the appropriate action must still be rapidly executed without a loss in decision performance.

The fifth training objective is to increase skill retention. While initial training receives a great deal of attention, maintenance and retention of necessary skills may receive less, especially during times of war and rapid re-deployment cycles. Thus, a major objective of any training program should be to consider that the skills necessary for threat detection may require further training in the future in order to maintain a high level of skill readiness. Ensuring training allows Soldiers to reach their needed level of performance is paramount for Soldiers to conduct successful military operations. As mentioned before, skills of different types may decay at various rates (Wisher, Sabol, & Ellis, 1999). Thus, it would behoove researchers and trainers to consider two products of ARI's effort involving skill retention: the "User's Manual for

Predicting Military Task Retention" and the "User's Decision Aid" (Rose, Radtke, Shettel, & Hagman, 1985a; Rose, Radtke, Shettel, & Hagman, 1985b).

The following two training objectives will likely be achieved if the above objectives are met, but training could also focus specifically on changing typical mindsets for TD and ensuring that TD skills become more 'automated' as a result of training. Much research in the area of decision science has fostered the idea that changing your frame can be a functional exercise, especially because it may expose information that would otherwise be unrecognized and, thus, unprocessed (Hammond, Keeney, & Raiffa, 1999; Russo & Schoemaker, 2002). Unfortunately, much of this research applies to slower analytical decision making, which may not be informative and functional for application in a visual scan situation (i.e., dismounted patrol). Nevertheless, Klein (2003; see also Zsambok & Klein, 1997) has shown that intuition, which can be viewed as a form of framing, can be functional in a situation requiring immediate attentiveness, recognition, and action. However, overcoming our natural and learned biases takes practice, but skills can operate as intuitive reactions once learned. For instance, the Marine Combat Hunter Course (X-file, 3-35.3x, pg. 17) teaches Soldiers to scan from right to left rather than left to right. Scanning in this manner is proposed to protect against a learned bias, due to learning to read right to left, and will allow Soldiers to not skip over any details when using the biased scanning approach. A version of changing frames is experienced by Soldiers who serve as opposing force (OPFOR), because they practice exploiting gaps of our own operational forces.

As suggested by Stokes et al, a means for improving pilot performance would be to provide students access to a variety of instances or experiences and, thus, build their experiential catalog. Though they studied the aviation domain, this suggestion is generally applicable and supported by more recent research by Taatgen, Huss, Dickison, and Anderson (2008). Taatgen et al, emphasized both the importance of cued recognition by the environment and task knowledge stored in memory. Thus, the integration of top down or endogenous information with bottom up or exogenous information is likely the best model for supporting how problems are solved and, with practice, automatizing of processes and actions become more possible. Pashler (1992) speculated that this automatizing is one potential explanation for how humans can concurrently perform multiple complex tasks. The ability of threat detection has to become so habitual that Soldiers forget they are doing it, while concomitantly overcoming their paranoia and anxiety caused by an asymmetric environment. Like wearing a watch or clothes, we eventually habituate to their presence and only now and then become briefly aware of them. Once the execution of skills become less reliant on conscious control, we are no longer aware, nor need to be, of all the behaviors and cognitions needed to carry out the action. We just do it. As skill level moves from novice towards expert, the training objectives outlined above become less conscious.

Methods to Train Threat Detection Skills

Deliberate Practice: Physical (Overt Performance)

Though there is no substitute for in-theatre operational experience, training can be conducted that provides Soldiers with skills that can be utilized in operational settings. As noted earlier, deliberate practice is focused repetition of a task with appropriate feedback. This

provides a safe environment where a task can actually be practiced allowing deliberate practice principles to be initiated. For instance, Soldiers could perform a task (i.e., performing a dismounted patrol), with a mentor who actively provides constructive feedback; for instance, the mentor can provide a comparison between the Soldier's performance and an expert's performance. Deliberate practice is likewise about thinking and/or performing like an expert. An intended result of deliberate practice or becoming more expert is to perform a task less consciously than a novice. Thus, as skills become easier to perform, they are moving from controlled processes to more automatic (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

Through the acquisition of skill, the performer begins to automate performance, allowing mental resources to be freed for task-related or other purposes. As stated earlier how long it takes to reach expert performance is debatable, but deliberate practice has been shown to be effective for non-military tasks such as chess and military tasks such as battlefield decision making (Shadrick, Crabb, Lussier, & Burke, 2007) and crisis response (Shadrick, Schaefer, & Beaubien, 2007). Since a visual space, especially in a dynamic situation with multiple moving elements, is full of information, deliberate training on how to handle this influx of information is compulsory. Likewise, a static visual space, with little movement can also be difficult to perform well in, because it promotes a potentially more complacent, less-aroused state of participation by the viewer. Both situations may also require the viewer recognizing what is absent, not just what is present in a scene that is of importance. How to train threat detection skills, attentiveness, recognition, and action in respect to both dynamic and static visual spaces provides context for development of physical performance skills.

Deliberate Practice: Mental (Imagination/Visualization)

The mentored repetition of physical tasks is necessary for current operations, but not as much attention is given to mental preparation such as visualization. Research involving imagination has illustrated that it is a functional method for improving learning and subsequent task performance (Cooper, Tindall-Ford, Chandler, & Sweller, 2001; Driskell, Copper, & Moran, 1994; Leahy & Sweller, 2008). Davoli and Abrams (2009) have explored the manipulation of what they called the "peripersonal space". This space is an imaginary area that extends outward from a person and likely assists interaction with the local environment, especially close to the body of an individual. Their research has identified that imagined posture, specifically that involving the hands, can slow down processing time for items in a visual display. The more time spent processing a particular item, the more information can be gathered about it. This finding correlates with a study by Williams, Singer, and Frehlich (2002) showing that experts have a longer "quiet eye period" or the time between final target fixation and the initiation of a motor response.

As technologies advance allowing actual operational environments to be captured in various media formats (i.e., pictures, video), trainers can take advantage of this by incorporating this media into training. For instance, providing footage of a patrol route before Soldiers have to traverse it, could illustrate what areas of a given route are more likely to provide concealment for IED emplacement and give Soldiers an advantage they would not otherwise have. Likewise, mentally visualizing how the enemy might utilize the visual environment is a tactic taught in such courses as the Marine Combat Hunter Course.

Combined: Overt and Mental

By deliberately engaging in guided tasks, the desired behaviors/skills are trained and engaging in those behaviors results in the achievable training outcomes. One method to combine both physical and mental methods is to perform actions an enemy would use (i.e., OPFOR) in order to manifest a model of the situation to better attune Soldiers' visual skills for detection of and reaction to threat. Gesturing can be a means of manipulating the visual space (Ehrlich, Levine, & Goldin-Meadow, 2006). For instance, having Soldiers actually perform the motor actions of emplacing an IED, in a container or in the ground could be beneficial to engage in to better understand the enemy's perspective. Thus, rather than simply imagining or visualizing the route and rather than simply performing a patrol without previous knowledge, the act of gesturing can prime a mental model for the situation. By enacting a model, important features of a particular route would be more accessible. This enactment could guide all skills, by guiding attention to specific aspects of a route and readying information in the mind so that it is more available for a recognition process, and, likewise, priming the steps of appropriate action once recognition provides a target.

Etnier and Landers (1996) examined methodical variations on two aspects of procedural variables that could affect the outcome of results concerning mental practice. They studied the effect of the duration of mental practice as well as whether participants engaged in physical or mental practice first; they also noted that amount of physical practice, the perspective the user takes when engaging in mental practice, and the performer's experience with a given task could also affect results involving mental practice. This option that would not necessarily require a great deal of time commitment and would be done individually. Although Etnier and Landers conclude that a delay period between engagement in mental practice and actual subsequent performance may be the vital variable, persons who performed physical practice first (followed by mental practice) always performed better, collectively, than participants performing mental practice first. Although performance between participants in the different mental practice conditions (1,3,5, or 7 minutes) did not significantly differ, by the final trial, those participants who had engaged in longer periods of mental practice did respectively better than those who engaged in shorter periods of practice. Though mental practice or visualization may not always be an option for Soldiers, pre-exposure to patrol routes, for instance, could enhance ability to detect threats via familiarization with an AO and this can be accomplished with little to no resources and a small obligation of time.

Training Format

Simulations/Video Games (lab)

Technology has an important place in research and certainly in training. There are a variety of interactive programs available including, *Virtual Battle Space (VBS) 2.0, DARWARS, America's Army, Dismounted Infantry Virtual After Action Review System (DIVAARS)*, and *DIVE.* However, units need to be able to leverage technology to meet their needs, but not become so reliant on it that they cannot execute effective training without it. Varying levels of fidelity work well for TD training. The difficulty often lies with ensuring there is an effective transfer of training and that the basic necessary skills are not sacrificed for simulation aesthetics.

Researchers from ARI have also explored the use of virtual environments and simulations to enhance training. For instance, Pleban and Salvetti (2003) explored the use of virtual environments as means for dismounted infantry mission rehearsal, while Gately, Watts, Jaxtheimer, and Pleban (2005) explored the use of a virtual training environment to improve the effectiveness of after action reviews for dismounted infantry operations. A more recent review of virtual training found that skills necessary for dismounted operations, such as marksmanship and situation awareness, are benefited by virtual immersive simulations (Knerr, 2007).

As noted above, advantages may be given by providing actual operational environment footage. For training, a primary question is how to deliver such information and, if this information is not available, what are the best alternatives for illustrating the training objectives without losing a functional edge. Considering multiple formats and levels of fidelity is one means of addressing the need for operational skills such as threat detection. Pringle (2007) recently noted, simulations have continued to play an important role in small arms training for both the Army and Marine Corps. One possibility is to take advantage of simulations that have become more realistic, in terms of graphic quality and are more flexible for achieving various training needs. A recent example of this is the multiplayer online role-playing game called, "Asymmetric Warfare Virtual Training Technology" or AW-VTT (Peck, 2005). This simulation allows Soldiers preparing for deployment to interact, online, with Soldiers already in theatre. Thus, knowledge transfer of how to handle checkpoint routines can be accomplished online in a realistic simulation with real-time information from deployed Soldiers.

Another example of the effective use of such technology is the implementation of vignette based simulations to train such skills as battlefield thinking (Shadrick, Crabb, Lussier, & Burke, 2007). This training was developed to provide Battalion (and Company) level commanders with a strategy that could be utilized to better envision how to adapt to and exploit information for operational success. Vignettes have also been successfully utilized to train crisis response, both for planning and implementation of crisis response plans (Schaefer, Shadrick, Beaubien, & Crabb, 2008).

There is also evidence that engaging in playing video games can improve a variety of cognitive skills, including those that are normally not under conscious or top-down control. As noted below, several studies also share the conclusion that these skills can be transferred to another version of the target task or simply improve overall cognitive performance, especially involving vision. For instance, Shapiro and Raymond (1989), basing their research on Yarbus (1967), illustrated that scan paths, including foveations, can be improved through simple strategies utilizing video games. They showed the 'efficient' group had fewer foveations and a better score than the 'inefficient' group. Thus, visual attention can be controlled and exploited to improve visual performance. Another example of improving selective visual attention via video game play was noted by Green and Bavelier (2003). They showed that video game players had a greater visual attentional capacity, had better spatially-distributed visual attention, and were better at switching between visual tasks such as identification and detection. To control for the potential confound that video game players might naturally have better visual attention skills, they trained non-video game players on an 'action' game vs. non-action game. The action game required exercising all of the above identified skills, whereas the non-action game did not. After

only 10 days (one hour each day), all participants showed improved visual performance, with the action game group showing significantly superior visual performance.

Barlett, Vowels, Shanteau, Crow, and Miller (2009) showed that cognitive performance (including selective visual attention) can be improved by engaging in either violent or non-violent video game play. Effects were the result of only short-term exposure; either video game was engaged in for less than 20 minutes. Likewise, the games were not standardized in terms of amount of action nor concentration needed to play them, but both groups did show improvement on cognitive performance compared to a control group whom did not engage in video game play.

An aspect of training that can serve as a barrier for many training topics and applications is how to deliver the information such that information is distributed the quickest and can be utilized the most efficiently. The TD skills are all trainable across various formats, but training to improve them can be hampered by the over reliance on technologies that do not speak to basic learning principles; the training application should be easily employed and rapidly available without requiring a complex delivery mechanism. An example of such a mechanism is game-based tools, such as video games. Castel, Pratt, and Drummond (2005) noted that video game players performed faster than non-video game players on complex visual search tasks and identified targets more readily. Green and Bavelier (2003; see also Barlett, et al., 2009) provide further evidence that playing action video games can increase performance for a number of visual skills such as target detection and tracking. Though the short-term effects of video games have not always been demonstrated as desirable (Anderson & Ford, 1986), when they are coupled with the proper training format and mentorship, the potential benefits should outweigh the costs.

Photos/Real footage (lab)

Another potential training format that could assist in the training of the threat detection skill set is the use of photos and/or real footage. The use of stills or photos was utilized by Cockrell (1979) to train target identification; groups receiving degraded images performed best when retested later on that same level of degradation. Similarly, Kowalski-Trakofler and Barrett (2003) used degraded images to improve skills of hazard recognition for miners. By using images that made the hazard less obvious via the amount of clutter or noise in a photo, the image was stated to be degraded; the photos used were of real scenes of mines. Importantly, miners trained with the degraded images performed better on a hazard recognition task than a group receiving regular images.

Training and operational exercises (field)

Soldiers have to practice the skills they have been taught prior to, during, and after deployment. One recent example of integrating media with real performance, is the Rules of Engagement (ROE) Live Fire Simulator being utilized by the Norwegian military (Schaathun & Skagen, 2008). In this training, Soldiers practice rules of engagement by interacting with an image projected on a screen in real-time; behind the screen is a range berm. Soldiers are given a weapon with live rounds. On the opposite side of the direction of fire and within range for effective verbal communication is the role-player, (being shown on the screen via a video camera)

ready to interact in real-time with the Soldier on point. This type of training provides a realism of which would be encountered during actual operations without jeopardizing the safety of Soldiers.

A great deal of technology exists that has been developed to aid in IED detection and defeat. However, when technology fails or when it is unavailable, Soldiers have to be able to fall back on basic skills that allow them to maintain mission effectiveness. Despite efforts to give a technological advantage to Soldiers, human-centered training is essential for missions in the current operational environment. If the technologies fail or are unavailable, the Soldier still needs to know what to do when. Training has to be effective while integrating limits of human capacities, especially when technology is involved (Chapman & Underwood, 1998; Durso & Dattel, 2006). Human beings have an innate ability to process and comprehend complicated visual scenes. The information necessary for identification can be accomplished very rapidly; approximately 100 milliseconds (Potter, 1976). Despite the impressive nature of the human visual system, as with any of our information processing systems, there are extant limitations. Wolfe, Horowitz, and Michod (2007) found that picture memory can be disrupted by additional tasks such as visual search. Wolfe et al., noted a similar finding by Allport, Antonis, and Reynolds (1972) indicating that auditory interference was greater for auditory stimuli than for visual stimuli. Thus, multiple tasks involving mental resources for the same sensory modality can impair performance in that modality. These factors need to be considered for training both in lab and field settings.

Future Research

ARI's mission is to improve Soldier, leader, and unit performance through advances in the behavioral and social sciences focused on personnel, organizations, training, and leader development. TD has always been and will continue to be a requisite ability of the American Soldier. Based on the components of TD identified in this paper and the needs of the Army, future research directions on TD, set within ARI's military training and leader development framework, can lead to improvements in overall Army readiness, particularly operational unit effectiveness. There are three major areas of research including, and encompassed in, sport psychology that should be explored to better inform future research efforts involving TD. These are briefly explored in sequence below and include better understanding and utilization of methodologies from sport psychology, better understanding the role of the effects of emotional factors on training, and measuring performance under stress. Likewise, a comprehensive understanding of threat detection from a research perspective can inform at least two broad operational concerns. These are discussed in addition to the major areas of research and include animate threats, such as potential threats within a local population and inanimate threats, such as IEDs. A particular concern involving animate threats involves rules of engagement (ROE) and escalation of force (EOF) procedures, which guide Soldiers' interactions with a local populace. ROE and EOF direct when a Soldier may appropriately react with varying levels of force.

As noted in a special issue of *Military Psychology* (Vol. 20, Supplement 1), sport psychology can provide a number of parallels to studying the military domain. These include, particularly studying emotion and attention as they relate to a variety of performance (Janelle & Hatfield, 2008). For instance, ineffective gaze behavior can affect processes enveloped under

attention. Findings such as those can be important for Soldiers, especially in an uncertain environment where visually detecting cues of potential threats is imperative. Further, Ward, et al., (2008) suggest that skills relevant in sports domains, encompassed broadly by perceptual and cognitive processing, can inform research and training in a military context. For example, improving recognition, part of an anticipatory response, as part of military training can be accomplished using findings from sport psychology research. Further, understanding how athletes move from novice to more proficient performance can be assessed for military purposes using similar techniques and procedures as those used when studying behavior in sports.

The role of emotion, particularly fear, is a necessary factor to consider for a research program aimed at understanding the short-term and enduring consequences of affective factors on Soldier performance. Being a Soldier on a battlefield can be fear-inducing and anxiety-provoking, two states which can debilitate performance. However, Becker (2009), for instance, has noted that inducing the state of fear can positively affect visual search for non-threatening persons or objects; information which may be important to fully understand a situation. Thus, visual search, which is the vital perceptual component of threat detection, may be positively influenced simply by inducing a general state of fear. In contrast, Bocanegra and Zeelenberg (2009) demonstrated that emotional factors can improve some components of visual processing, while actually impairing others.

Hancock (2009) noted, really understanding how stress (and fear) affects performance requires great care in the implementation of psychological methodology and being able to rethink traditional views on the effects of stress. For instance, as noted by Driskell and Salas (1996), stress, in a variety of forms, has been shown to degrade performance in a number of military contexts, especially performance involving visual search. Understanding the link between emotion, stress, and performance, by using methodologies from sport psychology, could greatly inform visual threat detection research and military training.

In addition to the three research areas, there are two operational concerns, animate and inanimate threats, that can guide future research. A main pillar of full spectrum operations is consideration of the population which Soldiers are inherently required to work with and around (FM 7-0, *Training For Full Spectrum Operations*). The detection of threats is, thus, complicated by necessary, population-centric considerations. As noted at the beginning of this report, insurgents purposefully intermingle with local populations making their detection exceedingly difficult. In order to accomplish the overarching Army mission in current and future operational environments, the burden will be carried by Soldiers on the ground. The ROE and EOF procedures guide Soldiers' behavior when engaging both the enemy and civilian population. A psychological research initiative examining how Soldiers implement ROE and EOF as well as adapt to changes in those measures could inform both individual and collective tasks. Specifically, an examination of these procedures will better inform when and why effective procedures are used and also how and why procedures breakdown from a behavioral perspective. Further, examining how these actions could positively and negatively influence TD across OEs could lead to improvements in TD performance and, possibly, improvements in the methods used to engage a local population.

The Army will continue to engage the enemy and work with civilian populations in asymmetric OEs. Inherent within those settings is an ever-increasing reliance on IEDs to upset

the local population's chances to ensure law and order in their neighborhoods and disrupt Army operations aimed at developing a population's infrastructure. Though several technologies have been developed to help mitigate the use of IEDs, evaluation, detection, and defeat will continue to be carried by the Soldier in the foreseeable future. The best tool for threat detection is the human eye coupled with a highly trained Soldier's mind. Despite the continual development of new technologies to mitigate the IED threat, the human end-user (i.e., the Soldier) must still make the final decision about what determines a threat and what response is appropriate.

Eye-tracking methodologies and technologies (ETMT) is a mechanism that can assist in exploring the research areas and the noted operational concerns. For instance, ETMT can inform how visual threat detection is affected by changes to ROE and EOF procedures. ETMT could be used in research to determine the optimal places for Soldiers to look for cues that may inform when an escalation in deterrent force is needed. This mechanism could likewise be used to make improvements in performance by providing objective performance feedback. ETMT can also be used to enhance understanding of the intricacies of visual threat detection by better revealing the necessary cognitive and perceptual processes. ETMT includes psychological research methods and tools for tracking eye movements without necessarily relying on advanced technology and software.

ETMT may augment training and measurement methods by allowing monitoring of visual attention and visual memory processes of Soldiers performing behaviors critical for TD. The use of ETMT to train skills is a more recent exploitation of this research tool. For instance, Kostons, van Gog, and Paas (2009) demonstrated that the use of ETMT can improve performance for novice, and more expert performers, at least in terms of self-assessment. Further, ETMT has also been shown to be an effective tool for capturing and assessing performance of the visual system, which can be used to inform training applications (Boot, Neider, & Kramer, 2009). Understanding how to use this research tool as an aid for training TD is currently an unexploited use of ETMT. Eye-tracking research is typically done in a laboratory setting, but can be used to gather performance information in field settings, which, in turn, supplements further research and informs training on TD. Future research that integrates the research areas noted above with operational concerns such as detecting IEDs, while relying on ETMT, will greatly benefit further understanding of the critical skills needed for visual threat detection.

Summary and Conclusions

An obstacle Soldiers must currently deal with and will likely continue to do so in the future, is the asymmetric environment. Asymmetric environments can change in threat level very rapidly after remaining docile for several months previous. This report identified three interactive contexts from which Soldiers can acquire information about their operational environment, including human activity, the terrain, and from the technology that accompanies them during operations in order to better mitigate the threats inherent in irregular environments.

Three relevant theories for studying attention and threat detection include ACT-R, signal detection theory, and the recognition-primed decision model. These paradigms serve to guide two main research pathways, visual attention and visual memory. Each of these provides a

method for developing and assessing the skills necessary for threat detection, attentiveness, recognition, and action. Signal detection theory is suited for examining target/threat detection within the context of individual ability and motivation, important for understanding attentiveness. ACT-R is especially suited for understanding skill acquisition and recognition processes important for understanding the skill of recognition. Finally, the recognition-primed decision model provides a platform for studying higher-order reasoning and decision making involved in threat detection, useful for studying the action skill.

While maintaining cognizance of the dynamicity of the irregular operational environment, including the three interactive contexts, five training objectives may be met that follow directly from the research program proposed. These include a reduction in errors, and an increase in speed, flexibility, robustness, and skill retention. By better understanding attentiveness, from a visual attention and visual memory perspective, the research results will lead directly to an improvement in visual threat detection skills. A better understanding of visual attentiveness will lead to better training methods for quicker acquisition of valid threats regardless of the environment and level of distraction embedded in that environment. Further, the skills outlined in this proposal are fundamental in that they can be practiced repeatedly in a variety of contexts without the need for developing a full training exercise.

As noted in the Future Research section, utilizing advances in both simulation and also techniques for measuring psychological activity will likely lead to advances in understanding of the skills related to threat detection, such as attentiveness, recognition, and action. Coupling those technologies with reliable psychological methodologies for studying behavior will lead to a better conception of threat detection behavior. Likewise, understanding the current and future needs of the Army involving threat detection will allow useful results of such research to be functionally integrated into requisite training for threat detection. Such training could likely benefit such missions as route clearance and/or dismounted patrol operations.

As pointed out by Killion, Bury, Pontbriand, and Belanich (2009), researchers have to understand the physiological, emotional, and cognitive effects of stressful environments while taking advantage of new technologies to improve Soldier performance. The literature and doctrine reviewed for this report suggest a research and training program adequately focused on understanding the human dimension of the operational environment, the skills of threat detection, and the dynamicity of the asymmetric environment can be initiated and sustained for current and future operational environments.

References

Alexander, J. B. (2009). Africa: Irregular warfare on the dark continent. Report 09-5. Joint Special Operations University.

Allport, D. A., Antonis, B., & Reynolds, P. (1972). On the division of attention: A disproof of the single channel hypothesis. *Quarterly Journal of Experimental Psychology, 24,* 225-235.

Anderson, J. R. (1976). *Language, memory, and thought.* Hillsdale, NJ: Erlbaum.

Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review, 89,* 369-406.

Anderson, J. R. (1983). *The architecture of cognition*. Cambridge, MA: Harvard University Press.

Anderson, C.A., & Ford, C. M. (1986). Affect of the game player: Short-term effects of highly and mildly aggressive video games. *Personality and Social Psychology Bulletin, 12,* 390-402.

Anderson, J. R., & Schunn, C. D. (2000). Implications of the ACT-R learning theory: No magic bullets. In R. Glaser (Ed.)*, Advances in instructional psychology (Vol. 5).* Mahwah, NJ: Erlbaum.

Barlett, C. P., Vowels, C. L., Shanteau, J., Crow, J., & Miller, T. (2009). The effect of violent and non-violent computer games on cognitive performance. *Computers in Human Behavior, 25,* 96-102.

Becker, M. W. (2009). Panic search: Fear produces efficient visual search for non-threatening objects. *Psychological Science, 20,* 435-437.

Becker, M. W., & Detweiler-Bedell, B. (2009). Early detection and avoidance of threatening faces during passive viewing. *The Quarterly Journal of Experimental Psychology, 62,* 1257-1264.

Bell, K. (2009). Pulling teeth: An infantry platoon leader's perspective on a year in Afghanistan. *ARMY Magazine,59,* 44-54.

Bocanegra, B.R., & Zeelenberg, R. (2009). Emotion improves and impairs early vision. *Psychological Science, 20,* 707-713.

Boot, W.R., Neider, M.B., & Kramer, A.F. (2009). Training and transfer of training in the search for camouflaged targets. *Attention, Perception, & Psychophysics, 71,* 950-963.

Brooks, K.R., & Gillam, B.J. (2007). Stereomotion perception for a monocularly camouflaged stimulus. *Journal of Vision, 7,* 1-14.

Brickner, M., & Gopher, D. (1981). *Improving time-sharing performance by enhancing voluntary control of processing resources.* (Rep. No. HEIS-81-3). Haifa, Israel: Technion III, Faculty of Industrial Engineering and Management, Research Center for Work Safety and Human Engineering.

Brown, S. D., & Steyvers, M. (2009). Detecting and predicting changes. *Cognitive Psychology, 58,* 49-67.

Center for Army Lessons Learned (2008, November). *Soldiers' Handbook, No. 09-02. The first 100 days*. Available at: http://call.army.mil

Castel, A. D., Pratt, J., & Drummond, E. (2005). The effects of video game experience on the time course of inhibition of return and the efficiency of visual search. *Acta Psychologica, 119*, 217-230.

Chapman, P. R., & Underwood, G. (1998). Visual search of driving situations: Danger and experience. *Perception, 27,* 951-964.

Chisholm, P. (2005). Clearing the Roads. *Special Operations Technology, 3.* Retrieved from http://www.special-operations-technology.com/article.cfm? DocID=1129

Cockrell, J. T. (1979). *Effective training for target identification under degraded conditions.* (ARI Technical Paper 358). U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA.

Cohen, R. (April, 2009). 10 problems with technology. Why some military systems get used and others collect dust. Retrieved from *http://www.afji.com/2009/04/3939965/.*

Cooper, G., Tindall-Ford, S., Chandler, P., & Sweller, J. (2001). Learning by imagining. *Journal of Experimental Psychology: Applied, 7,* 68-82.

Cowan, N. (1998). *Attention and Memory: An Integrated Framework.* New York: Oxford University Press.

Cowan, N. (2005). *Working memory capacity*. New York: Psychology Press

Dark, V. J., Vochatzer, K., & VanVoorhis, B. A. (1996). Semantic and spatial components of selective attention. *Journal of Experimental Psychology: Human Perception and Performance , 22*, 63-81.

Davoli, C. C., & Abrams, R. A. (2009). Reaching out with the imagination. *Psychological Science, 20, 293-295.*

Driskell, J. E., Copper, C., & Moran, A. (1994). Does mental practice enhance performance? *Journal of Applied Psychology, 79,* 481-492.

Driskell, J.E., & Salas, E. (Eds.). (1996). *Stress and human performance.* Mahwah, NJ: Lawrence Erlbaum.

Dubik, J.M. (April, 2009). Learning at the speed of war. Retrieved from http://www.ausa.org/_layouts/1033/Custom404.aspx?aspxerrorpath=http://www.ausa.org/publications/armymagazine/armyarchive/april2009/Pages/LearningattheSpeedofWar.aspx.

Dukewich, K. R., & Klein, R. M. (2009). Finding the target in search tasks using detection, localization, and identification responses. *Canadian Journal of Experimental Psychology, 63,* 1-7.

Durlach, P. J., Kring, J. P., & Bowens, L. D. (2008). Detection of icon appearance and disappearance on a digital situation awareness display. *Military Psychology, 20*, 81-94.

Durso, F. T., & Dattel, A. R. (2006). Expertise and transportation. In *The cambridge handbook of expertise and expert performance.* New York, NY: Cambridge University Press.

Dyer, J. L., Centric, J. H., & Wampler, R. L. (2007, January). *A case for decentralized training.* (ARI Research Report 1866). U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA.

Dyer, J. L., & Salter, R.S. (2001). *Working memory and exploration in training knowledge and skills required by digital systems.* (ARI Research Report 1783). U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA.

Edwards, W. (1962). Subjective probabilities inferred from decisions. *Psychological Review, 69*, 109-135.

Ehrlich, S. B., Levine, S. C., & Goldin-Meadow, S. (2006). The importance of gesture in children’s spatial reasoning. *Developmental Psychology*, *42*, 1259-1268.

Endsley, M. R. (2003). The role of situation awareness in naturalistic decision making. (pp. 269-283). In C. E. Zsambok & G. Klein (Eds.), *Naturalistic Decision Making*. Mahway, NJ: Lawrence Erlbaum.

Engle, R.W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science,11*, 19-23.

Ericsson, K. A., Krampe, R. T., & Tesch-Romer, C. (1993). The role of deliberate practice in expert performance, *Psychological Review*, *100*, 363-406.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data* (Rev.) Cambridge, MA: Bradford Books/MIT Press.

Etnier, J. L., & Landers, D. M. (1996). The influence of procedural variables on the efficacy of mental practice. *The Sport Psychologist, 10*, 128-140.

Finkbeiner, M., & Palermo, R. (2009). The role of spatial attention in nonconscious processing. *Psychological Science, 20*, 42-51.

Fisk, A. D., Lloyd, S. J. (1988). The role of stimulus-to-rule consistency in learning rapid application of spatial rules. *Human Factors, 30,* 35-49.

Fite, J.E., Breidert, J.T., & Shadrick, S.B. (September, 2009). *Initial evaluation of a U.S. Army training need: Soldier skills to develop, enhance, and support local level host-nation governance.* (Research Report 1912). U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA.

Fitts, P. M. (1964). Perceptual-motor skill learning. In A. W. Melton (Ed.). *Categories of human learning.* New York: Academic Press, 1964.

Fuller, R. G. C. (1983). *Prolonged heavy vehicle driving performance: Effects of unpredictable shift onset and duration and convoy vs. independent driving conditions*. (ARI Technical Report 585). U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA.

Gately, M. T., Watts, S. M., Jaxtheimer, J. W., & Pleban, R. J. (2005). *Dismounted infantry decision skills assessment in the virtual training environment.* (ARI Technical Report 1155). U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA.

Gibson, J. J. (1986). *The ecological approach to visual perception.* Hillsdale, NJ: Lawrence Erlbaum.

Gigerenzer, G., & Todd, P. M. (1999). *Simple heuristics that make us smart*. Oxford: Oxford University Press.

Gladwell, M. (2005). *Blink.* New York: Little Brown and Company.

Gopher, D. (1993). Attentional control: Acquisition and execution of attentional strategies. In D.E. Meyer and S. Kornblum (Eds.), *Attention and performance XIV: Synergies in experimental psychology, artificial intelligence, and cognitive neuroscience,* pp. 299-322. Cambridge, MA: MIT Press.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423,* 534-537.

Green, D. M., & Swets, J. A. (1966). *Signal detection theory and psychophysics.* New York: Wiley.

Grossman, D. (1996). *On killing: The psychological cost of learning to kill in war and society.* New York: Back Bay Books.

Grossman, D., & Christensen, L. W. (2004). *On combat. The psychology and physiology of deadly conflict in war and peace.* Belleville, IL: PPCT Research Publications.

Hammond, J. S., Keeney, R. L., & Raiffa, H. (1999). *Smart Choices: A Practical Guide to Making Better Decisions.* Boston: Harvard Business School Press.

Hancock, P.A. (2009). Performance on the very edge. *Military Psychology, 21,* S68-S74.

Hill, R.W., Kim, J.M., Zbylut, M.R., Gordon, A.S., Ward, J.N., & Vowels, C.L. (2008). Learning the lessons of leadership: Case method teaching with interactive, computer-based tools and film-based cases. (ARI Technical Report 1226). Arlington, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Hollingworth, A. (2009). Two forms of scene memory guide visual search: Memory for scene context and memory for the binding of target object to scene location. *Visual Cognition, 17,* 273-291.

Hollingworth, A., & Luck, S. J. (2009). The role of visual working memory in the control of gaze during visual search. *Attention, Perception, & Psychophysics, 71,* 936-949.

Janelle, C. M., & Hatfield, B. D. (2008). Visual attention and brain processes that underlie expert performance: Implications for sport and military psychology. *Military Psychology, 20,* S39-S69.

Johnson-Laird, P. (1983). *Mental models: Towards a cognitive science of language, inference, and consciousness.* Cambridge, MA: Harvard University Press.

Jones J., & Pashler H. (2007). Is the mind inherently forward looking? Comparing prediction and retrodiction. *Psychonomic Bulletin & Review,14,* 295-300.

Kane, M.J., Poole, B.J., Tuholski, S.W., & Engle, R.W. (2006). Working memory capacity and the top-down control of visual search: Exploring the boundaries of “executive attention”. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32,* 749-777.

Killion, T. H., Bury, S. J., de Pontbriand, R., & Belanich, J. (2009). United States army science and technology: Sustaining soldier performance. *Military Psychology, 21,* S9-S22.

Klein, G. (1997). An overview of naturalistic decision making applications. In C.E. Zsambok & G. Klein (Eds), *Naturalistic decision making.* (pp. 49-60). Mahwah, NJ: Erlbaum.

Klein, G. (1998). *Sources of Power.* Cambridge, MA: MIT Press.

Klein, G. (2003). *Intuition at Work.* (pp. 86-108). New York: Doubleday.

Knerr, B. W. (2007). *Immersive simulation training for the dismounted soldier.* (ARI Study Report 2007-01). U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA.

Köhler, W. (1969). *The task of Gestalt psychology*. Princeton, NJ: Princeton University Press.

Kostons, D., van Gog, T., & Paas, F. (2009). How do I do? Investigating effects of expertise and performance-process records on self-assessment. *Applied Cognitive Psychology, 23,* 1256-1265.

Kowalski-Trakofler, K., & Barrett, E. A. (2003). The concept of degraded images applied to hazard recognition training in mining for reduction of lost-time injuries. *Journal of Safety Research, 34,* 515-525.

Kramer, A.F., Larish, J.F., & Strayer, D.L. (1995). Training for attentional control in dual-task settings – a comparison of young and old adults. *Journal of Experimental Psychology: Applied, 1*, 50-76.

Leahy, W., & Sweller, J. (2008). The imagination effect increases with an increased intrinsic cognitive load. *Applied Cognitive Psychology, 22,* 273-283.

Lehrer, J., (2009). Magic and the brain: Teller reveals the neuroscience of illusion. Retrieved from http://www.wired.com/science/discoveries/magazine/17-05/ff_neuroscienceofmagic.

Leipold, J. D. (2009). Study aims to identify IED detection experts. Retrieved from http://www.army.mil/-news/2009/04/03/19247-study-aims-to-identify-ied-detection-experts/

Li, S. Y. W., Blandford, A., Cairns, P., & Young, R. M. (2008). The effect of interruptions on postcompletion and other procedural errors: An account based on the activation-based goal memory model. *Journal of Experimental Psychology: Applied, 14,* 314-328.

Livingston, M. A.; Brown, D. G.; Julier, S. J.; Schmidt, G. S. (2006). Mobile augmented reality: Applications and human factors evaluations. In *Virtual Media for Military Applications* (pp. 25-1 – 25-16). Meeting Proceedings RTO-MP-HFM-136, Paper 25. Neuilly-sur-Seine, France: RTO.

Lyon, D. R., Gunzelmann, G., & Gluck, K. A. (2008). A computational model of spatial visualization capacity. *Cognitive Psychology, 57*, 122-152.

Macknik, S. L., Mac King, J. R., Robbins, A., Teller, J. T., & Martinez-Conde, S. (2008). Attention and awareness in stage magic: Turning tricks into research. *Nature Reviews Neuroscience, 9,* 871-879.

Mandler, G. (1979). Organization and repetition: Organizational principles with special reference to rote learning. In L.G. Nilson (Ed.), *Perspectives on memory research* (pp.293-327). Hillsdale, NJ: Lawrence Erlbaum Associates.

Mandler, G. (2008). Familiarity breeds attempts: A critical review of dual-process theories of recognition. *Perspectives on Psychological Science, 3*, 391-399.

McMaster, H. R. (2009, Winter). The human element: When gadgetry becomes strategy. *World Affairs.* Retrieved from http://www.worldaffairsjournal.org/2009%20-%20Winter/full-McMaster.html

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63,* 81-97.

Monk, C. A., Trafton, J. G., & Boehm-Davis, D. A. (2008). The effect of interruption duration and demand on resuming suspended goals. *Journal of Experimental Psychology: Applied, 14,* 299-313.

Mueller, S. T. (2009). A bayesian recognitional decision model. *Journal of Cognitive Engineering and Decision Making, 3,* 111-130.

Murphy, J.S. (Ed.). (2009). Identifying experts in the detection of improvised explosive devices (IED2). Unpublished manuscript.

Nagl, J. A. (2002). *Learning to eat soup with a knife: Counterinsurgency lessons from Malaya and Vietnam.* Westport, CT: Praeger Publishers.

Nagl, J. A. (2009). Let's win the wars we're in. *Joint Force Quarterly, 52*, 20-26.

Pashler, H. (1992). Attentional limitations in doing two tasks at the same time. *Current Directions in Psychological Science, 1,* 44-48.

Peck, M. (2005, February). Soldiers learn hazards of war in virtual reality. Retrieved from http://www.nationaldefensemagazine.org/archive/2005/February/Pages/default.aspx.

Piper, B. (April 12, 2008). Every marine a hunter: Support marines take combat hunter course. Retrieved from http://www.marines.mil/units/marforcom/iimef/26thmeu/Pages/EveryMarineaHunterSupportMarinestakeCombatHunterCourse.aspx.

Pleban, R. J., & Salvetti, J. (2003). *Using virtual environments for conducting small unit dismounted mission rehearsals.* (ARI Research Report 1806). U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA.

Poiese, P., Spalek, T. M., & Lollo, V. D. (2008). Attentional capture by a salient distractor in visual search: The effect of target-distractor similarity. *Canadian Journal of Experimental Psychology, 62,* 233-236.

Potter, M.C. (1976). Short-term conceptual memory for pictures. *Journal of Experimental Psychology: Human Learning and Memory, 5*, 509-522.

Pringle, R. L. (2007, July). Small arms training. *Military Training Technology, 12,* 10-13.

Radvansky, G. A. (2008). *Comprehension and memory of spatial and temporal event components.* (ARI Technical Report 1221). U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA.

Ratwani, R. M., & Trafton, J. G. (2008). *Spatial memory guides task resumption*. (NRL MR 5510). Naval Research Laboratory, Navy Center for Applied Research in Artificial Intelligence, Washington, D.C.

Rensink, R. A. (2000). Seeing, sensing, and scrutinizing. *Vision Research, 40,* 1469-1487.

Rensink, R. A., O'Regan, J. K., & Clark, J. J. (1997a). To see or not to see: The need for attention to perceive changes in scenes. *Psychological Science, 8,* 368-373.

Rensink, R.A., O'Regan, J.K., & Clark, J.J. (1997b). On the failure to detect changes in scenes across brief interruptions. *Visual Cognition, 7,* 127-145.

Rose, A., Radtke, P., Shettel, H., & Hagman, J. (1985a). *User's manual for predicting military task requirements.* (Research Product 85-13). U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA.

Rose, A., Radtke, P., Shettel, H., & Hagman, J. (1985b). *User's manual for predicting military task requirements.* (Research Product 85-26). U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA.

Russo, J. E., Carlson, K. A., Meloy, M. G., & Yong, K. (2008). The goal of consistency as a cause of information distortion. *Journal of Experimental Psychology: General, 137,* 456-470.

Russo, J. E., & Schoemaker, P. J. H. (2002). *Winning Decisions: Getting it Right the First Time.* New York: Doubleday.

Savick, D. S., Elliott, L. R., Zubal, O., & Stachowiak, C. (2008, April). *The effect of audio and tactile cues on soldier decision making and navigation in complex simulation scenarios.* (ARL-TR-4413). U.S. Army Research Laboratory, Aberdeen Proving Ground, MD.

Scales, R.H. (2009). Clausewitz and World War IV. *Military Psychology, 21*, S23-S35.

Schaathun, P., & Skagen O. (2008, September). The ROE live fire simulator. Increasing individual skills under ROE conditions. Retrieved from http://www.mca-marines.org/gazette/sept08_schaathun.asp.

Schaefer, P. S., Shadrick, S. B., Beaubien, J., & Crabb, B. T. (2008). *Training effectiveness assessment of red cape: Crisis action planning and execution.* (ARI Research Report 1885). U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA.

Schendel, J. D., & Johnston, S. D. (1982). *A study of methods for engaging moving targets.* (ARI Technical Report 590). U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA.

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Perceptual learning, automatic attending and a general theory. *Psychological Review, 84,* 1-66.

Schunn, C. D., Saner, L. D., Kirschenbaum, S. K., Trafton, J. G., & Littleton, E. B. (2007). Complex visual data analysis, uncertainty, and representation. In M. C. Lovett & P. Shah (Eds.), *Thinking with Data*. Mahwah, NJ: Erlbaum.

Shadrick, S. B., Crabb, B. T., Lussier, J. W., & Burke, T. J. (2007). *Positive transfer of adaptive battlefield thinking skills.* (ARI Research Report 1873). U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA.

Shadrick, S. B., & Lussier, J. W. (2004). *Assessment of the Think Like a Commander training program.* (ARI Research Report 1824). U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA.

Shadrick, S. B., & Lussier, J. W. (2009). Training complex cognitive skills: A theme-based approach to the development of battlefield skills. In, K. Anders Ericsson (Ed.), *Development of Professional Expertise*. Cambridge, Cambridge University Press.

Shadrick, S. B., Schaefer, P. S., & Beaubien, J. (2007). *Development and content validation of crisis response training package red cape: Crisis action planning and execution.* (ARI Research Report 1875). U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA.

Shanteau, J. (1987). Psychological characteristics of expert decision makers. In, J. L. Mumpower, O. Renn, L.D. Phillips, & V.R.R. Uppuluri (Eds.), *Expert judgment and expert systems.* Berlin: Springer-Verlag.

Shanteau, J. (1992a). How much information does an expert use? Is it relevant? *Acta Psychologica, 81,* 75-86.

Shanteau, J. (1992b). The psychology of experts: An alternative view. In G. Wright & F. Bolger (Eds.), *Expertise and Decision Support*. Plenum Press, NY, 1992. (pp.11-23).

Shapiro, K. L., & Raymond, J. E. (1989). Training of efficient oculomotor strategies enhances skill acquisition. *Acta Psychologica, 71,* 217-242.

Shiffrin, R. M., & Schneider, W. (1977b). Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. *Psychological Review, 84,* 127-190.

Simons, D. J. (2000). Current approaches to change blindness. *Visual Cognition, 7,* 1-15.

Simons, D. J., & Chabris, C.F. (1999). Gorillas in our midst: Sustained inattentional blindness for dynamic events. *Perception, 28*, 1059-1074.

Simons, D. J., & Levin, D. T. (1998). Failure to detect changes to people during a real-world interaction. *Psychonomic Bulletin & Review, 5,* 644-649.

Smith, P.L., & Ratcliff, R. (2009). An integrated theory of attention and decision making in visual signal detection. *Psychological Review, 116*, 283-317.

Staszewski, J. J., & Davison, A. (2000). Mine detection training based on expert skill. In A.C. Dubey, J.F., Harvey, J.T. Broach, & R.E. Dugan (Eds.), *Detection and remediation technologies for mines and mine-like targets V, Proceedings of Society of Photo-Optical Instrumentation Engineers 14th Annual Meeting*, SPIE, 4038, 90-101.

Staszewski, J. J. (1999). Information processing analysis of human land mine detection skill. In V. T. Broach, A. C. Dubey, R. E. Dugan, & J. Harvey, (Eds.), *Detection and Remediation Technologies for Mines and Minelike Targets IV*, Proceedings of the SPIE Conference, Vol. 3710, pp. 766-777.

Steinberg, R., & Kornguth, S. E. (2009). Sustaining performance under stress: Overview of this issue. *Military Psychology, 21*, S1-S8.

Stokes, A. F., Kemper, K., & Kite, K. (1997). Aeronautical decision making , cue recognition, and expertise under time pressure. In, C. E. Zsambok & G. Klein (Eds.), *Naturalistic Decision Making.* Mahwah, NJ: Lawrence Erlbaum. (pp. 183-196).

Taatgen, N. A., Huss, D., Dickison, D., & Anderson, J. R. (2008). The acquisition of robust and flexible cognitive skills. *Journal of Experimental Psychology: General, 137,* 548-565.

Taleb, N. N. (2007). *The black swan.* New York: Random House.

Trickett, S. B., Trafton, J. G., & Saner, L. D., & Schunn, C. D. (2007). "I don't know what is going on there": The use of spatial transformations to deal with and resolve uncertainty in complex visualizations. In M. C. Lovett & P. Shah (Eds.), *Thinking with Data*. Mahwah, NJ: Erlbaum.

Tversky, A. (2004). Preference, belief, and similarity. (Ed.) Eldar Shafir. Cambridge, MA: MIT Press,

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185,* 1124-1131.

U.S. Department of Army (2009, May). *Army Posture Statement*. Washington DC: Author.

U.S. Department of Army. (2006, December). Field Manual 3-24, *Counterinsurgency* Washington DC: Author.

U.S. Department of Army (2009, August). Field Manual 3-21.8, *The Infantry Rifle Platoon and Squad.* Washington DC Author.

U.S. Department of Army (2009, August). Field Manual 3-21.9, *The SBCT Infantry Rifle Platoon and Squad*. Washington DC: Author.

U.S. Department of Army (2008, December). Field Manual 7-0, *Training For Full Spectrum Operations*. Washington DC: Author.

U.S. Department of Army (2006, October). Field Manual 3-06, *Urban Operations*. Washington DC: Author.

U.S. Department of Army. (2008, April). *The Army Lawyer.* (DA Pamphlet 27-50-419). Bagwell, R. The threat assessment process (TAP): The evolution of escalation of force.

U.S. Department of Army. (2007, December). *Soldier's Manual of Common Tasks: Warrior Skills, Level 1.* Washington DC: Author.

U.S. Department of Army. (2006, October). *The United States Army Concept for Tactical Maneuver, 2015-2024.* Washington DC: Author.

U.S. Department of Defense. (2009, August). Joint Publication 1-02, *Department of Defense Dictionary of Military and Associated Terms.* Washington DC: Author.

U.S. Department of Defense. (2007, September). *Irregular Warfare, Joint Operating Concept.* Washington, DC: Author.

U.S. Marine Corps. (2007, October). X-File 3-35.3x, *Combat Hunter: Observe, Move and Act Tactics, Techniques and Procedures (TTPs*). Quantico, VA. Marine Corps Warfighting Laboratory.

Ward, P., Farrow, D., Harris, K.R., Williams, A.M., Eccles, D.W., & Ericsson, K.A. (2008). Training perceptual-cognitive skills: Can sport psychology research inform military decision training? *Military Psychology, 20,* S71-S102.

Werner, S., & Thies, B. (2000). Is “change blindness” attenuated by domain-specific expertise? An expert-novice comparison of change detection in football images. *Visual Cognition, 7,* 163-173.

Williams, A. M., Ericsson, K. A., Ward, P., & Eccles, D. W. (2008). Research on expertise in sport: Implications for the military. *Military Psychology, 20,* S123-S145.

Williams, A. M., Singer, R. N., & Frehlich, S. G. (2002). Quiet eye duration, expertise, and task complexity in a near and far aiming task. *Journal of Motor Behavior, 34,* 197-207.

Winn, W. (1993b). A constructivist critique of the assumptions of instructional design. In T.M. Duffy, J. Lowyck, & D.H. Jonassen. (Eds.), *Designing environments for constructive learning.* New York: Springer.

Wisher, R. A., Sabol, M. A., & Ellis, J. A. (1999). Staying sharp: Retention of military knowledge and skills. (Special Report 39). U.S. Army Research Institute for the Behavioral and Social Sciences. Alexandria, VA:

Wolfe, J. M., Horowitz, T. S., & Michod, K. O. (2007). Is visual attention required for robust picture memory? *Vision Research, 47,* 955-964.

Yarbus, A. L. (1967). *Eye movements and vision.* New York: Plenum Press.

Zbylut, M.L., Metcalf, K.A., Kim, J.M., Hill, Jr., R.W., Rocher, S., & Vowels, C.L. (2007). Army excellence in leadership (AXL): A multimedia approach to building tacit knowledge and cultural reasoning. (ARI Technical Report 1194). Arlington, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Zsambok, C.E., & Klein, G. (1997). *Naturalistic Decision Making*. Mahway, NJ: Lawrence Erlbaum.